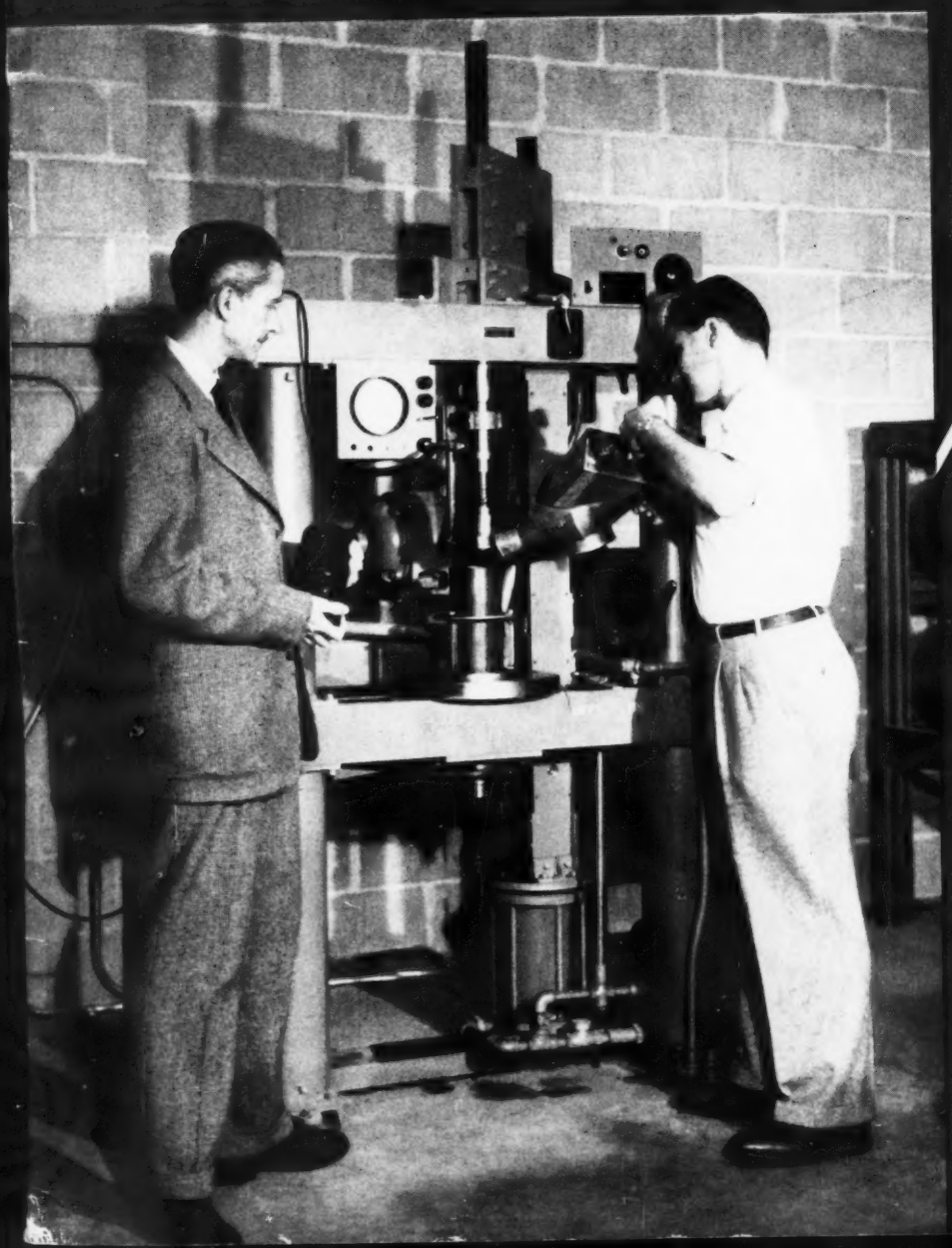
# The TREND IN ENGINEERING

at the University of Washington



In this issue:


- Triaxial Kneading Compactor
- Road Builders to Meet
- Steam Plants and the Northwest Power Shortage: Part II
- Fish-Tag Tests Favor New Design
- Olivine as a Source of Magnesium
- Cold Experts Confer
- Moisture Condensation on Show Windows



January, 1952

VOL. 4, No. 1

# CHEMIST AS SEER

LET ME TURN TO MY CRYSTAL BALL and try and glimpse the outlines of the balance of the 20th century. . . . The fine structure of the future is beyond the resolving power of my equipment. Therefore, the new scientific discoveries, the new theories, the various minor revolutions in physics and inorganic chemistry are not discernible. . . . What must be described are the slow but steady changes in the production of energy and food. The era of liquid fossil fuels is, by the close of the century, coming to an end, and the worry about future coal supplies is increasing. . . . Atomic energy has not proved to be an expedient way of lengthening the period in which man taps the sources of energy stored in the earth's crust. Solar energy, on the other hand, is already of significance . . . and by the end of the century is the dominating factor in the production of industrial power. The practical utilization of this inexhaustible source of energy, together with the great changes in the production of food, has already had enormous effects on the economic and hence political relations of nations. With cheap power, the economical production of fresh water from sea water has become a reality.

"The problem of conserving the fossil fuels still left has become closely related to the problem of the economic production of carbon monoxide. Each era of the world came up with different answers, but as the century came to a close those answers appeared to be converging. The underground gasification of coal, the conversion of cheap crops into process gas are just two of the ways found for supplying the chemical factories of each nation with adequate raw material."

—James Bryant Conant in his address before the Diamond Jubilee Meeting of the American Chemical Society, *Chemical and Engineering News*, September, 1951. Copyright by the American Chemical Society and reprinted by permission of the copyright owners.

THE ENGINEERING EXPERIMENT STATION of the University of Washington was established in December, 1917, to coordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;
(2) to undertake extended research and to publish reports on engineering and scientific problems;
(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgy, Ceramics
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. The results of the investigations are published in the form of bulletins, technical notes, and reports. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

January, 1952

# The TREND IN ENGINEERING

## at the University of Washington

Vol. 4 No. 1

Published quarterly in January, April, July, and October, by the Engineering Experiment Station at the University of Washington to reflect the current highlights of its accomplishments and to report progress in its program of investigation and research.

ENGINEERING EXPERIMENT STATION

*Director*.....F. Burt Farquharson

*Assistant Director*.....Warren W. Philbrick

*Editor*.....Isabel W. Hemenway

EXPERIMENT STATION BOARD

Harold E. Wessman, *Dean of the College of Engineering*, Chairman

Austin V. Eastman
Fred S. Eastman
F. Burt Farquharson
George E. Goodspeed
Bror L. Grondal
John H. Manley
Bryan T. McMinn
R. Wells Moulton
Drury A. Pifer
Robert B. Van Horn

PUBLICATION COMMITEE

F. Burt Farquharson
Bror L. Grondal
Robert G. Hennes
W. Ryland Hill

PUBLICATION OFFICE

127 More Hall
University of Washington
Seattle 5, Washington

Entered as second-class matter March 7, 1949, at the post office at Seattle, Washington, under the act of August 24, 1912.

## CONTENTS

The Triaxial Institute Compactor *Martin Ekse* . . . 5

Road Builders to Meet in February . . . . . 7

Steam Plants and the Northwest Power Shortage: Part II
*Floyd D. Robbins* . . . . . 9

University Engineers on Science Program . . . . . 14

Lignite Process Hits the Mark . . . . . 15
(Reprinted from *Chemical Engineering*)

Fish-Tag Tests Favor New Design
*Dayton L. Alvarson, Harry H. Chenoweth* . . . . 17

Nonlinear Servomechanism Research Under Way . . . 19

Olivine Qualifies for Ceramic Uses . . . . . 20

Olivine as a Source of Magnesium
*Norman Ketzlach, R. W. Moulton* . . . . . 21

Moisture Condensation on Enclosed Show Windows
*Theodore L. Gershun* . . . . . 25

Conference of National Coal Experts Prepares for Urgent State Development . . . . . 29

Engineering Research Dividends . . . . . 30

Notes and Comments

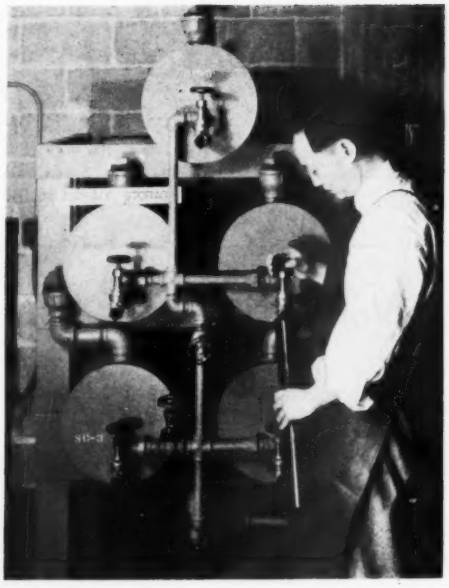
Engineers in the News
New Research Projects
New Reprints

### COVER

Professor Robert G. Hennes of the Civil Engineering Department holds sample of bituminous paving mixture which has been tested, while Ben K. Rippe, graduate student, pours mixture for another test into Triaxial Institute Compactor. Note oscilloscope added to the original design of the machine by the Engineering Experiment Station to permit observation and recording of time-pressure distribution.

*Left*
R. L. CUMMINS, civil engineering graduate, mixing sample for triaxial test.

*Right*
DAVID LIU, civil engineering graduate student, drawing asphalt from storage tank.



*Left*
Equipment for testing stability of bituminous mixtures.

*Below*
DAVID LIU crushing aggregate to required size.

*Below*
R. L. CUMMINS placing batch in large mixer.

# THE TRIAXIAL INSTITUTE KNEADING COMPACTOR

MARTIN EKSE

*Assistant Professor of Civil Engineering*

Martin Ekse

The Civil Engineering Department of the University of Washington has recently acquired a compacting machine for the fabrication of soil samples and bituminous mixture samples in the laboratory. The machine has been installed and completely calibrated and has been used in making test specimens of bituminous concrete in the department's highway design course. It is expected that considerable use will be made of the machine for research work both in soils and in bituminous mixtures.

Better control in the fabrication of laboratory test specimens in the design of bituminous mixes has long been needed. Manual tamping of the mixtures into forming molds often results in variation and inconsistencies in test results that are difficult to explain or interpret, even though the tamping process has been well standardized and carefully followed in the laboratory. Compaction of the mixtures into the molds by the application of static loads may also result in test properties which are quite different from the properties of the same mixture compacted on the roadway with a roller and subjected to the action of traffic.

The Triaxial Institute is sponsor of the development program that has resulted in the design and manufacture of the compactor. The Institute was created in 1948 primarily for the purpose of developing, standardizing and promoting the principles of triaxial testing. It consisted of the following members:

V. A. Endersby, Shell Development Co., *Chairman*
H. E. Davis, University of California
N. M. Finkbiner, Oregon State Highway Department
R. G. Hennes, University of Washington
F. N. Hveem, California Division of Highways
Vaughn Smith, California Research Corporation
Bailey Tremper, Washington State Highway Department

Design of the compactor was made by F. N. Hveem based on the experience gained in the use of kneading compactors by the California Division of Highways, the California Research Corporation, and the Shell Oil Company laboratories. Some critical points in the design were the extent of lift of the tamping foot, its dimensions and shape, the overlap of successive tamping applications, the speed and dwelling time on the sample, rate of feed and length of tamping time per unit height of specimen, and type of mold and mold lining. The first model was made by the University of California Institute of Transportation and Traffic Engineering in accordance with recommendations of the Triaxial Institute.

It is well recognized that the smooth roller, in compacting the bituminous mixture on the roadway, and the subsequent action of traffic on the pavement surface provide a kneading action to the mixture in the process of compaction. This kneading action results in a combination of stability and density which has been difficult to duplicate in the laboratory mainly because of the difference in orientation of aggregate particles. That is, since stability of the mixture is primarily dependent on aggregate interlock, it is possible in the fabrication of the laboratory test specimen to attain a high stability in the mixture and still have a low bulk specific gravity or high porosity. This is especially true if only a static load with double plungers is used. With the application of rodding or tamping to the mixture in the mold along with the static load, a reorientation of aggregate particles takes place and the same stability may be attained with higher bulk specific gravity or lower porosity.

Since low porosity (2 to 5 per cent) is desirable in the final compacted pavement to avoid possibility of too much water absorption, the asphalt content in the pavement must be carefully controlled if the desirable properties of stability, durability, and watertightness in the final compacted pavement on the roadway are to be maintained. Thus the laboratory test specimen must in all respects be representative of the field compacted mixture if laboratory design results are to be truly indicative of field performance.

The Triaxial Institute Kneading Compactor, with the kneading action provided by the tamping foot to the mixture in the rotating mold and the multiplicity of control of the magnitude and duration of applied pressure, makes possible the duplication in the laboratory of field orientation of aggregate particles and field densities.

Figures 1 and 2 depict schematically the mechanical tamping system and the control system of the

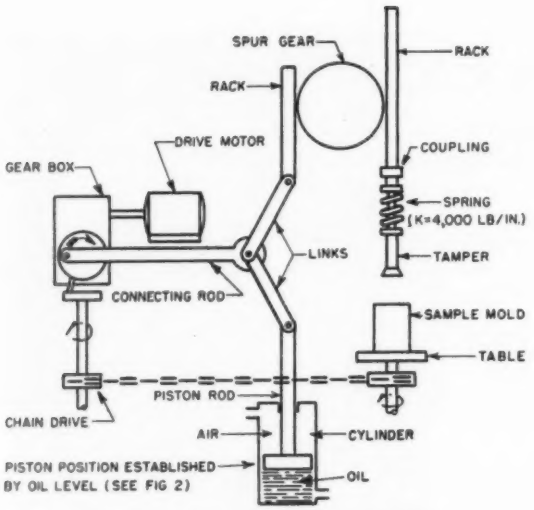



FIG. 1. MECHANICAL TAMPING SYSTEM

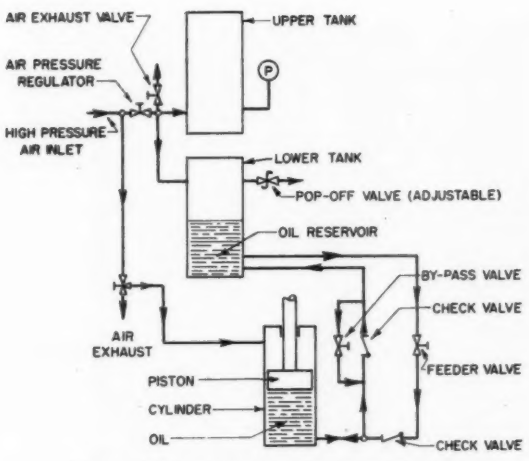



FIG. 2. HYDROPNEUMATIC CONTROL SYSTEM

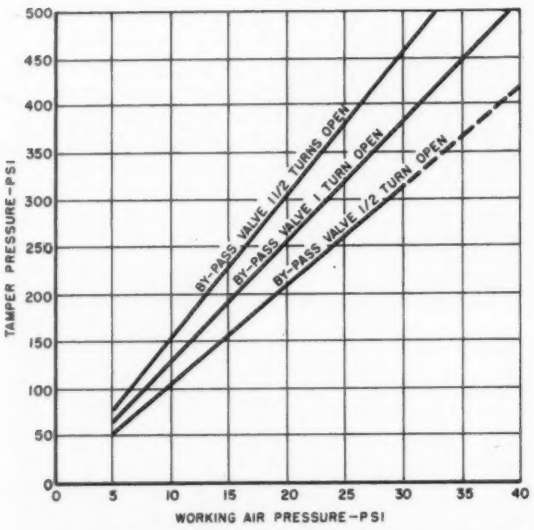

TAMPER PRESSURE-PSI
WORKING AIR PRESSURE-PSI
BY-PASS VALVE 1 1/2 TURNS OPEN
BY-PASS VALVE 1 TURN OPEN
BY-PASS VALVE 1/2 TURN OPEN

FIG. 3. CHART FOR DETERMINING WORKING AIR PRESSURE

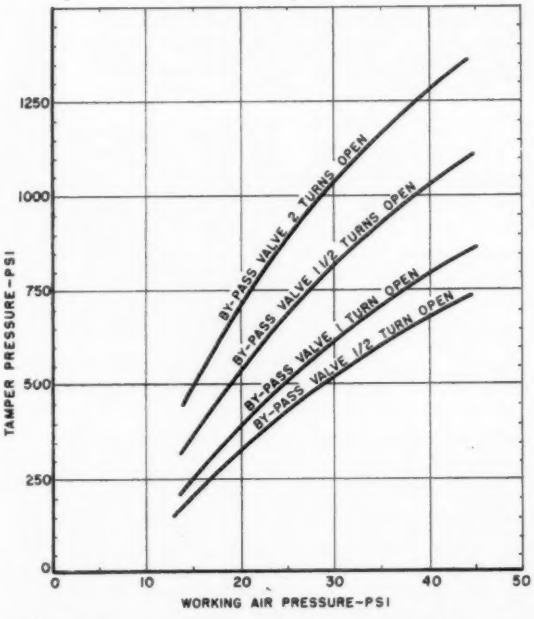

TAMPER PRESSURE-PSI
WORKING AIR PRESSURE-PSI
BY-PASS VALVE 2 TURNS OPEN
BY-PASS VALVE 1 1/2 TURNS OPEN
BY-PASS VALVE 1 TURN OPEN
BY-PASS VALVE 1/2 TURN OPEN

FIG. 4. RESULTS OF CALIBRATION OF U. OF W. COMPACTOR

compactor. The toggle-press principle employed in the mechanical system provides an action which builds up the pressure gradually, without impact, on the tamping foot and allows it to dwell on the specimen for a fraction of a second (up to about ½ second) before being gradually released. The table on which the sample mold rests then rotates a fraction of a turn before the next pressure is applied.

The shape of the base of the tamping foot is outlined by three approximately equal circular arcs of 2-inch radius. The corners are rounded to ¼-inch radius. The length of chord across one arc is about 2½ inches. The area of the base is 3.2 square inches.

The material is fed into the rotating mold and kneaded into place by the tamping foot at the rate of 30 tamps or cycles per minute. The short dwelling period at the bottom of the descent of the foot overcomes viscosity of the material. Rotation of the mold during tamping provides reorientation of aggregate particles and can be controlled by varying the time

of compaction or number of tamps along with tamping pressure.

The combination hydraulic-pneumatic control system with manually controlled valves makes possible a wide range of combinations of pressure intensity and duration, from a rather sharp crest on the load-time curve to a flat "dwelling" period of nearly ½ second of the 2-second cycle. Desirable tamping pressures for different air pressures in the control system may be determined from Fig. 3.

Calibration of the machine purchased by the Civil Engineering Department has recently been completed by the Engineering Experiment Station under the direction of Professor R. G. Hennes.

An oscillograph is used to record time-pressure curves for the machine operating under air pressures of from 15 to 40 pounds per square inch in the control system and with various openings of the by-pass valve. The results of this calibration are shown by the curves of Fig. 4.

A typical time-pressure curve for one cycle of the tamping operation is shown in Fig. 5.

An oscilloscope is now being installed on the machine by the Engineering Experiment Station, so that it will be possible to observe, and record if necessary, the diagram of time-pressure distribution during any cycle. Thus it will be possible to make a selection of desirable pressure distribution by adjustment of by-pass valve and air pressure while the pressure diagram is actually being observed in the oscilloscope.

From a practical standpoint, the machine serves a very useful purpose in many respects. In presenting the principles of good design of bituminous mixtures

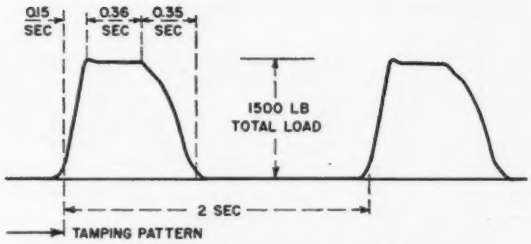



FIG. 5. TYPICAL TIME-PRESSURE CURVE

to students of highway engineering, it is essential to be able (1) to make duplicate specimens and (2) to eliminate fabrication procedure as a variable in specimens of different proportions compared for stability, durability, water absorption, etc. Good results in this respect have already been obtained.

Laboratory fabrication procedure, particularly with respect to compaction, can be coordinated with field compaction. Much has been done in this regard by the Washington State Highway Department by comparison of densities and other properties of pavement samples with those of laboratory specimens made with the kneading compactor and using the same proportioning of identical ingredients.

Higher densities were obtained in the laboratory with the kneading compactor than could be obtained in field construction, indicating that the amount and intensity of rolling during construction may need to be increased for best pavement performance. The attainment of higher densities during construction would tend to eliminate the uncertainty of further densification of the pavement under the action of traffic.

## Road Builders to Meet in February

The Fifth Northwest Conference on Road Building will be held in More Hall at the University of Washington on Wednesday through Friday, February 13-15, 1952. These meetings are attended by federal, state, county and city engineers, and by many other engineers interested in road building. The Conference provides a forum for the interchange of technical information and professional opinion on a broader basis than is possible in meetings attended by only one segment of the profession. Each of the past conferences has attracted between 200 and 300 participants, exclusive of student attendance. The 1952 Conference is sponsored by the Department of Civil Engineering at the University of Washington, and as in the past it is planned to publish the *Proceedings* through the cooperation of the Engineering Experiment Station. The broad regional nature of this affair will be emphasized even more by rotating the location of future meetings, with Oregon State College acting as host in 1953 at Corvallis.

A session on Highway Classification will be conducted under the chairmanship of Mrs. Julia Butler Hansen, who is also Chairman of the Joint Fact-Finding Committee on Roads, Streets and Bridges, appointed by the Washington legislature. The basis for proposed recommendations to the legislature on this subject will be thoroughly discussed.

Among prominent out-of-state speakers expected on the program are Mr. Carl Fritts of Washington, D. C., Chief Engineer for the Automotive Safety Foundation; Mr. Walter F. Winters, New York, Chief Engineer of the Asphalt Institute; Mr. Earl Miller, Chief Engineer of the Idaho Highway Department.

Important items on the program include the new test road being constructed by the eleven western states; the New Jersey turnpike; bridge and traffic paint; and the proposed Sound bridge.

PRINCIPAL COAL AREAS OF WASHINGTON

# STEAM PLANTS AND THE NORTHWEST POWER SHORTAGE

FLOYD D. ROBBINS
*Assistant Professor of Electrical Engineering*

## PART II: ECONOMIC CALCULATIONS FOR STEAM POWER IN THE NORTHWEST

SYNOPSIS

**A previous report* discussed the serious Northwest power shortage which cannot ease off until 1954 and, even assuming completion of present projects as planned, will not accumulate a safe margin before 1957. This shortage can be effectively and quickly relieved by construction of one or more modern steam power-generating stations. The chief advantages of steam over hydro plants are (1) location close to load centers, (2) more rapid construction, (3) less than one-third capital cost. The modern steam station can also compete on an economic basis with the hydroelectric project *at high values of annual plant factor*. At low values, since the cost per kilowatt hour is less than that of hydro, it represents an important adjunct to total power. Steam plants are a very desirable supplemental source of power in an integrated power system, such as the Northwest Power Pool, and would make it possible to realize the full power potential of such a system.**

### Fuels Available in Washington

The state of Washington has two major sources of fuel which have been used industrially for the generation of steam power: coal and wood. Neither fuel is presently used in the electric utility plants of the state, but both are used to some extent in industrial plants connected to the Northwest Power Pool. Wood and wood products may be eliminated from consideration because this fuel is usually fired in the form of sawdust and hogged fuel, which are by-products of the lumber industry and are not usually available in sufficient quantity to supply a steam plant of 300,000-kw capacity.[16]

Coal deposits of Washington are scattered along the western portion of the state in varying types of formations, with heat content of the coals varying from 7,500 to 13,300 Btu per pound as mined.[17] The total coal reserves in Washington have been estimated to be about 63,877,000,000 tons, classified as follows:[18]

| | |
|---|---|
| Anthracite | 23,000,000 tons |
| Bituminous | 11,412,000,000 tons |
| Subbituminous | 52,442,000,000 tons |

The location of these deposits appears on the map on the opposite page. The subbituminous deposits are of special interest in this report because they offer the best possibility of a supply of cheap coal quite suitable as fuel in a modern steam station. At least two veins of this type of coal, the Tono Bowl near Bucoda, Washington, and the Toledo vein near the town of that name, offer distinct possibilities of strip mining in large quantity at a very low cost. Both these fields would be in close proximity to a plant located at tidewater near Tacoma or on the Nisqually flats, or on the Columbia River near Vancouver or Longview, Washington.

The reserve at the Tono field is estimated to contain at least 57,400,000 tons. The total reserve in the Toledo vein is estimated to be about 5,300,000 tons[19] making a total of 62,700,000 tons immediately available for strip mining. This supply alone would supply a 300,000-kw steam plant running at 100 per cent annual plant factor for about 40 years. The Tono field in particular could expand its production to take care of such a steam plant in about 90 days after a contract for coal in such large amounts is assured. As will be shown later in this report, estimates based on extended investigation and discussion with coal operators indicate that coal delivered to the boiler bunkers at a location near Tacoma or Vancouver, Washington at $3.50 a ton or less is entirely feasible.

At present only a very small market exists for these subbituminous and bituminous coals so that construction of steam plants in this area would create practically a new market for an enormous potential resource not utilized now or needed for other purposes.

### Methods of Utilizing Coal

In addition to direct burning, other methods of utilizing coal have been considered as possibilities with a view to cutting fuel costs, notably gasification of coal at the mine, with supply to the steam plant being handled by pipe-line. In Washington it is generally not economically feasible to locate the steam plant at the mine owing to lack of adequate supply of cooling water for the condensers. (A 300,000-kw steam plant would require approximately 6.500 cubic feet of water per second, which is not available at the known coal-field sites.) The definite possibilities of the gasification method have already been ably discussed in another Engineering Experiment Station Report.[20]

* See Part I: "The Steam Plant in the Solution of the Power Problem," *The Trend in Engineering*, October, 1951.

Pierce and George[21] showed that the cost of transporting equivalent amounts of energy as coal by railroad and as gas by gas pipe-line would show a saving of approximately 25 per cent in favor of the gas pipe-line for distances up to 50 miles. The cost is further reduced in the case of gasification because the ash does not have to be transported. Underground gasification is still in the experimental stage and is not considered in this report to be practical as a source of fuel supply for a large steam station.[22]

Washington subbituminous coals are also well suited to low-temperature carbonization processes such as Lurgi-Spülgas,[23] National Fuels Corporation,[20] and Coalene.[24] The N.F.C. process has proved successful in the carbonization of subbituminous coal quite similar in characteristics to the Washington coal.[25] Products from the carbonization process, such as benzine, paraffin, Diesel oil, heating oil, phenol, and road tar, are all valuable, and the char is an excellent fuel for steam plants. The two-fold effect on a balanced economy of (1) the highly valuable by-products and (2) the char as steam-plant fuel, would clearly contribute to the industrial welfare of this region and is well worth further discussion and study.* The cost per Btu of coal delivered to the steam-plant as char would, under such circumstances, be lower than the cost per Btu when delivered as raw coal, thus lowering the cost of power as estimated in this report for a coal-burning plant.† With total utilization of by-products in a favorable market and with a 100 per cent plant factor, the advantage of this process is tremendous,[26] and, even disregarding the by-products, appears to provide a sound margin. Of course operation at 100 per cent plant factor in the Northwest is likely to apply only to some of the large companies which are plagued at present by an interruptible power contract.

**Other Fuels**

The possibility of natural gas being carried into this area by pipe-line is a real one, though not in the immediate future. Application to construct this pipeline has been made to the Federal Power Commission. If it is approved, construction will take approximately one and one-half years. There is every indication that the output of the first line would be taken for industrial and residence heating and consequently would not be available in large quantities at low cost to the steam station. However, when it is available at a competitive price, it is an ideal fuel for a large steam plant and would be a very fine combination with a coal gasification project. The matter of adapting the boilers of the steam plant to fire gas is rather simple and presents no engineering problems.

Oil, though of course a highly desirable fuel for a steam plant, has four distinct disadvantages: (1) since it is not produced in the Pacific Northwest, it cannot contribute to the industrial economy of the region; (2) for the same reason, its shipping cost is high; (3) its use is likely to be severely curtailed in times of national emergency when the steam plants are most needed; (4) its many other uses, both domestic and commercial, tend to cause a wide fluctuation in market price. However, since oil is highly satisfactory as a fuel in many modern steam plants throughout the United States, it is used in this report as a means of comparison with other fuels.

It is well to point out here that oil might be a logical choice for a small isolated plant where power is needed with a minimum of delay. Such plants using gas turbines might serve as interim sources of power to supplement the steam plants.[27] Extended tests by the U.S. Naval Experiment Station seem to indicate that this type of plant is a successful source of power supply.[28]

**Cost of Coal**

Low-rank coal, with its vast reserves in Washington, has been recognized by a number of competent engineers and investigators as the logical choice of fuel for steam-generating plants. In a recent report Conradi states:

> The fact that the region is desperately short in power and that only little relief can be counted on during the first five or six years, even if federal money for the various hydroelectric projects is appropriated, seems to indicate that a fair amount of steam-electric generating capacity should be installed as quickly as possible. Strip-mined subbituminous or maybe lignitic coal from southwestern Washington will be the proper fuel for these plants.[20]

Investigation shows that this coal can be delivered to the vicinity of Tacoma or Vancouver, Washington, at less than the $3.50 per ton in-bunker-price used in this report. Quoted here is an excerpt from a letter of February 6, 1951, received from Mr. Willis T. Batcheller, consulting engineer, Seattle, Washington.

> The published freight rate on coal from the Tono-Bucoda field to Nisqually Flats and vicinity is $1.34 per ton for single car-load lots. I have been assured that a special rate of not more than $1.00 per ton is available for an operation like the one proposed. This makes a total cost of coal delivered at the steam-electric plant of $3.00 per ton. . . .
>
> While strip mining is in progress, it is planned to prepare for completely mechanized underground mines requiring a minimum of labor and ultimately resulting in about the same production cost as the initial strip mining. The fact that the cost of coal produced by underground mining and delivered on the Ohio River for the Tidd plant of the American Gas and Electric Corporation is $3.14 and that similar grades of coal are available delivered in New York harbor for around the $3.00 per ton figure, appear to conclusively demonstrate the practicability of duplicating these costs for short rail hauls to Puget Sound and the Columbia River.

---

* See article which follows in this issue, "Lignite Hits the Mark," describing the new Alcoa project in Texas.

† See estimates for raw coal in Table III.

Mr. William Strain, manager of Strain Coal Company, Seattle, Washington, states in his letter of October 12, 1950, to Mr. Batcheller:

> . . . regarding the utilization of coal from the Tono area for steam generating purposes, I am submitting herewith the approximate results of our stripping operation in the No. 1 seam.
>
> Removing an overburden with a ratio of about 2 to 1, we have obtained costs of well below $3.00 per ton delivered in the railway car at the mine on a maximum production of 300 tons per day. . . .
>
> In view of our experience, it would be reasonable to assume that your estimated mine cost of $2.00 per ton on the railway car could be attained with a production of 3,000 tons per day. I would also agree that a freight rate of $1.00 per ton between the Tono field and Nisqually on such a large volume is a conservative estimate.

These two opinions are in close agreement with the conclusion reached by Mr. R. R. Montell, consulting engineer, Seattle, Washington. In a report to the Coal Producers Association,[29] he states:

> The necessary coal cost of $3 per ton delivered also indicates the necessity of either strip mining or fully mechanized [mining] on heavy and continuous seams with only slight pitch. That this cost is easily possible under such conditions is abundantly proven in Eastern coal fields and even indicated in the cost tabulation quoted from Eastern plants and showing delivery costs of $2.70 per ton.
>
> Costs of stripping at $1.75 per ton in the Big Horn Basin of Wyoming have been verbally reported to the writer with other Eastern costs below $2.00. . . . However, the low stripping costs are not unknown in Western Washington. The Bureau of Mines Technical Paper 699, P. 11, gives the estimated stripping costs 1946-47 of the limited Toledo lignite deposit at $1.60 per ton delivered to the railroad.
>
> A study of stripping costs . . . leads to the conclusion that the $1.60-$1.75 costs per ton are by no means impossible and that consequently, a $3.00 per ton delivered cost to the Nisqually plant site on 22 miles from the Bucoda seam is entirely within reason, especially for quantities in excess of 500,000 tons per year.

Published reports on the cost of coal delivered to the eastern stations mentioned by Mr. Montell are now available.[11] Several stations are cited here where the situation is analogous to the proposed stations in Washington. Prices are dollars per ton at the plant.

| | |
|---|---|
| Washburn Station, Washburn, N. Dakota, Otter Tail Power Co. | $3.05 |
| F. R. Phillips Station, South Heights, Pa., Duquesne Power Co. | 3.09 |
| Pine Grove Station, Pine Grove, Pa., Pennsylvania Power and Light Co. | 3.16 |
| Philo Station, Philo, Ohio, Ohio Power Co. | 3.23 |
| Tidd Station, Brilliant, Ohio, Ohio Power Co. | 3.47 |
| Osage Station, Osage, Wyoming, Black Hills Power Co. | 2.51 |

It must be concluded therefore that $3.50 coal delivered to a steam plant located near Tacoma, or Vancouver, Washington is a value quite conservative even in the face of rising costs.

In Mr. Holland Houston's comprehensive report prepared for the Washington State Department of Conservation, a value of $5.20 per ton was determined by using $3.50 as the mine cost and $1.70 for freight.[13] The author believes that both values are too high for strip mining and in quantities such as even one 300,000-kw steam station would require because the mining estimate is based on small current operations and the freight estimate on carload instead of trainload lots. However, in the calculations which follow, both of these values are used to show that, on the basis of even the higher estimate, steam-station power cost still compares favorably with that of hydroelectric power.

**Economic Analysis**

Typical calculations for a municipal plant, oil-fired, on a basis of 100 per cent plant factor and oil with 150,000 Btu per gallon, are as follows:

***Variable Expense (Fuel)***

Oil at $1.60 per barrel of 42 gallons
(Btu per barrel of oil=42×150,000=6,300,000)
Cost per barrel=$1.60 (1,600 mills)
(1 kwhr requires 11,000 Btu)

$$\text{Fuel cost}=\frac{11{,}000\times 1{,}600}{6{,}300{,}000}=2.79 \text{ mills per kwhr}$$

***Fixed Costs***[30]

| | *Mills per Kwhr* |
|---|---|
| Supervision, engineering | 0.039 |
| Station labor | 0.24 |
| Water, supplies | 0.054 |
| Maintenance | 0.26 |
| Total fixed costs | 0.593 |

***Fixed Charges***

*Interest.* Interest is taken at 2.0% per annum on capital investment of $150 per kilowatt.
150×0.02=$3.00/kwyr (3,000 mills)

$$\text{Cost}=\frac{3{,}000}{8{,}760}=0.342 \text{ mills/kwhr}$$

*Depreciation.*[31] Average depreciation is taken as 3.08% per annum on capital investment of $150 per kilowatt.
150×0.0308=$4.62/kwyr (4,620 mills)

$$\text{Cost}=\frac{4{,}620}{8{,}760}=0.526 \text{ mill/kwhr}$$

*Taxes.* Taxes are taken as 1% per annum on capital investment of $150 per kilowatt.
150×0.01=$1.50/kwyr (1,500 mills)

$$\text{Cost}=\frac{1{,}500}{8{,}760}=0.171 \text{ mill/kwhr}$$

*Total Fixed Charges*=1.039 mills per kwhr

*Summary of All Expenses*

*Variable Cost (Fuel)*

Total variable cost ..... 2.79 mills/kwhr

*Fixed Expenses*

Total fixed costs ..... 0.593 mill/kwhr

Total fixed charges ..... 1.039 mills/kwhr

Total fixed expenses ..... 1.632 mills/kwhr

Values for various annual plant factors are shown in Table II.*

**TABLE II**

**MUNICIPAL OR STATE STEAM PLANT, OIL-FIRED**

Values in Mills/Kilowatthour

| Annual Plant Factor (%) | 100 | 80 | 60 | 40 | 20 |
|---|---|---|---|---|---|
| Variable Expense (Fuel) (A) Total | 2.79 | 2.79 | 2.79 | 2.79 | 2.79 |
| Fixed Costs (B) | | | | | |
| Supervision-Engineering | 0.039 | | | | |
| Station Labor | 0.240 | | | | |
| Water and Supplies | 0.054 | | | | |
| Maintenance | 0.260 | | | | |
| Total | 0.593 | 0.742 | 0.989 | 1.482 | 2.962 |
| Fixed Charges (C) | | | | | |
| Interest (2% on investment) | 0.342 | | | | |
| Depreciation (3.08% on investment) | 0.526 | | | | |
| Taxes (1% on investment) | 0.171 | | | | |
| Total | 1.039 | 1.30 | 1.73 | 2.60 | 5.19 |
| Fixed Expenses (B+C) | 1.632 | 2.04 | 2.72 | 4.08 | 8.16 |
| Total Operating Expenses (A+B+C) | 4.42 | 4.83 | 5.51 | 6.87 | 10.95 |

For a coal-fired plant with coal costs at $3.50 and $5.20 per ton, all expenses will be the same as for oil, except fuel.

Since 9,000 Btu coal at $3.50 per ton corresponds to oil at $1.25 per barrel (Fig. 3†), the new fuel cost, for 100 per cent plant factor, will be:

$$\frac{11{,}000 \times 1{,}250}{6{,}300{,}000} = 2.18 \text{ mills/kwhr.}$$

Coal at $5.20 per ton corresponds to oil at $1.84 per barrel; the fuel cost under this condition will be:

$$\frac{11{,}000 \times 1{,}840}{6{,}300{,}000} = 3.21 \text{ mills/kwhr.}$$

* For Table I see Part I.

† See Part I.

Total costs for various annual plant factors are tabulated in Table III.

**TABLE III**

**MUNICIPAL OR STATE STEAM PLANT, COAL-FIRED**

Values in Mills/Kilowatthour

| Coal at $3.50 per Ton | | | | | |
|---|---|---|---|---|---|
| **Annual Plant Factor (%)** | **100** | **80** | **60** | **40** | **20** |
| Variable Expense (Fuel) | 2.18 | 2.18 | 2.18 | 2.18 | 2.18 |
| Total Fixed Expenses | 1.63 | 2.04 | 2.72 | 4.08 | 8.16 |
| Total Operating Expenses | 3.81 | 4.22 | 4.90 | 6.26 | 10.34 |
| **Coal at $5.20 per Ton** | | | | | |
| **Annual Plant Factor (%)** | **100** | **80** | **60** | **40** | **20** |
| Variable Expense (Fuel) | 3.21 | 3.21 | 3.21 | 3.21 | 3.21 |
| Total Fixed Expenses | 1.63 | 2.04 | 2.72 | 4.08 | 8.16 |
| Total Operating Expenses | 4.84 | 5.25 | 5.93 | 7.29 | 11.37 |

**TABLE IV**

**PRIVATE CORPORATION-OWNED STEAM PLANT, OIL-FIRED**

Values in Mills/Kilowatthour

| Annual Plant Factor (%) | 100 | 80 | 60 | 40 | 20 |
|---|---|---|---|---|---|
| Variable Expense: (A) Fuel | 2.79 | 2.79 | 2.79 | 2.79 | 2.79 |
| Fixed Costs: (B) | 0.593 | 0.742 | 0.989 | 1.482 | 2.962 |
| Fixed Charges: (C) Interest (4% on investment) | 0.684 | 0.854 | 1.140 | 1.710 | 3.42 |
| Depreciation (3.08% on investment) | 0.526 | 0.658 | 0.877 | 1.315 | 2.630 |
| Taxes (3% on investment | 0.513 | 0.642 | 0.855 | 1.481 | 2.565 |
| Profit (4% on investment) | 0.684 | 0.854 | 1.140 | 1.710 | 3.420 |
| Total Fixed Charges | 2.407 | 3.008 | 4.012 | 6.216 | 12.035 |
| Total Fixed Expenses (B+C) | 3.00 | 3.750 | 5.001 | 7.698 | 14.997 |
| Operating Expenses (A+B+C) | 5.79 | 6.54 | 7.79 | 10.488 | 17.787 |

For comparison with the state or municipal owned plant, values for a private corporation-owned plant were calculated. Fuel and fixed costs remain substantially the same. Interest in this case was taken as the R.F.C. rate of four per cent, with depreciation rate the same as for the municipal plant. Taxes were taken as approximately three times that of the state or municipal owned plant, or three per cent on the capital investment. To these charges must be added a reasonable profit on the investment, taken as four per cent. The values for various plant factors are tabulated in Table IV.

Table V shows expenses for the corporation-owned steam plant computed for coal. They are the same as shown in Table IV except for fuel.

**TABLE V**

**PRIVATE CORPORATION-OWNED STEAM PLANT, COAL-FIRED**

Values in Mills/Kilowatthour

| Annual Plant Factor (%) | 100 | 80 | 60 | 40 | 20 |
|---|---|---|---|---|---|
| Variable Expense (Fuel) | 2.18 | 2.18 | 2.18 | 2.18 | 2.18 |
| Total Fixed Expenses... | 3.00 | 3.750 | 5.001 | 7.698 | 14.997 |
| Total Operating Expenses..... | 5.180 | 5.930 | 7.181 | 9.878 | 17.177 |

The unit costs on the Cowlitz hydro project may now be calculated. Annual production costs, including station labor, maintenance, supervision and engineering, supplies and expenses, were taken as $1.90 per kilowatt of installed capacity.[32]

*Annual Production Costs:*
$1.9\times345{,}000=\$655{,}500$

*Interest* (2% on the capital investment):
$0.020\times136{,}000{,}000=\$2{,}720{,}000$

*Taxes* (1% of the capital investment):
$0.01\times136{,}000{,}000=\$1{,}360{,}000$

*Depreciation* (average 2.28% of the capital investment):[31]
$0.0228\times136{,}000{,}000=\$3{,}100{,}800$

*Operation and Maintenance of Transmission Lines and Substations:* $200,000

***Total Annual Fixed Expenses:*** $8,036,300

$$\text{Cost}=\frac{(8{,}036{,}300)\ (1{,}000)}{1{,}378{,}000{,}000}=5.84 \text{ mills/kwhr.}$$

Since 345,000 kw, if it could operate at 100 per cent plant factor, would produce annually

$345{,}000\times8{,}760=3{,}020{,}000{,}000$ kwhr,

this would represent, after 10 per cent line losses are deducted, an annual energy input at the load center of

2,718,000,000 kwhr.

The Cowlitz Project would then operate at an annual plant factor of no better than 50.7 per cent. Values for other plant factors are shown in Table VI.

Table VII includes the tabulations for cost of the Northwest Power Pool (non-federal hydro) compiled from Report No. 308[15] as described in Part I. The actual average plant factor was 65.4 per cent.

The same report estimated the value of future federal power projects as 4.46 mills at an annual plant factor of 75 per cent.[15] This amount would also be the cost of power when the benefit-to-cost ratio is unity. The values for various plant factors are tabulated in Table VIII.

**TABLE VI**

**COWLITZ HYDRO PROJECT MUNICIPAL OWNED**

Values in Mills/Kilowatthour

| Annual Plant Factor (%) | 100 | 80 | 60 | 40 | 20 |
|---|---|---|---|---|---|
| Total Costs..... | (5.84) | (5.84) | (5.84) | 7.28 | 14.52 |

**TABLE VII**

**NON-FEDERAL HYDRO (NORTHWEST POWER POOL)[15]**

Values in Mills/Kilowatthour

| Annual Plant Factor (%) | 100 | 80 | 60 | 40 | 20 |
|---|---|---|---|---|---|
| Total Costs..... | 4.54 | 5.80 | 7.74 | 11.60 | 23.2 |

**TABLE VIII**

**FUTURE FEDERAL HYDRO PROJECTS[15]**

Values in Mills/Kilowatthour

| Annual Plant Factor (%) | 100 | 80 | 60 | 40 | 20 |
|---|---|---|---|---|---|
| Total Costs..... | 3.34 | 4.18 | 5.57 | 8.37 | 16.72 |

Calculations for combination with Bonneville Power Administration using an oil-fired municipal plant as secondary, are as follows:

*BPA 80% of time:*
$0.80\times17.50 = 14.00$

*Steam Fixed Costs:*
$$\frac{1.632\times8{,}760\times1}{1{,}000}=14.30$$

*Steam Variable Costs (Fuel):*
$$\frac{0.20\times8{,}760\times2.79}{1{,}000}=4.89$$

$\$33.19$/kwyr

This corresponds to an over-all cost of:

$$\frac{33.19\times1{,}000}{8{,}760}=3.78 \text{ mills/kwhr.}$$

If coal were used for fuel, the combination shown above would give the over-all power cost:

$$\begin{aligned} &\textit{BPA 80\% of the time} && = 14.00 \\ &\textit{Steam Fixed Costs} && = 14.30 \\ &\textit{Fuel Costs (Variable)} \\ &\frac{0.20\times 8{,}760\times 2.18}{1{,}000} && = 3.82 \\ & && \$32.12/\text{kwyr} \end{aligned}$$

This corresponds to the over-all cost:

$$\frac{32.12\times 1{,}000}{8{,}760} = 3.64 \text{ mills/kwhr.}$$

**Summary**

Curves plotted from the data of the calculations presented here appeared in Part I of this report. They substantiate the author's assertion that the steam plant should play an important part in any power program to meet the present critical Northwest shortage. The modern steam station can be ready for service in a comparatively short time, can compete economically with hydro at any plant factor, and may be the means of developing and using one of Washington's hitherto neglected resources: subbituminous and lignitic coal.

Since the foregoing data were compiled, the Denver office of the U. S. Bureau of Mines, in a cooperative agreement with the Texas Power and Light Company, has released the news of a new process in providing fuel for power generation.[26] This process, a variation of low-temperature carbonization, will be applied commercially at a new aluminum smelting plant for Alcoa at Milam, Texas, where it is predicted that power cost will be 3.5 mills per kilowatthour, or, including sale of by-products, even as low as 2.5 mills.

According to V. F. Parry, Chief of the Denver laboratories, the process "is applicable to any coal of lesser rank than high volatile bituminous B, a bracket that includes 90 per cent of all western coals."

An account of the proposed plant and outline of the process follows this report.

**REFERENCES**
**(For references 1-15 see Part I of this report)**


16. "Available Wood for Industry, State of Washington," Institute of Forest Products, Uni. of Wash., January, 1951.
17. YANCEY, H. F., GEER, M. R., and DANIELS, J., "Analyses of Washington Coals—Supplement to T. P. 491," U.S. Bureau of Mines, T.P. 618 (1941).
18. DANIELS, JOSEPH, "Coal in Washington," Engineering Experiment Station Report No. 3, Uni. of Wash., 1934.
19. TOENGES, A. L., TURNBULL, L. A., and COLE, W. A., "Exploration, Reserves, Bed Characteristics and Strip-Mining Possibilities of a Lignite Deposit Near Toledo, Lewis County, Washington," U.S. Bureau of Mines T.P. 699 (1947).
20. CONRADI, L. A., "The Chemical Utilization of the Subbituminous Coals of Washington," Eng. Ex. Sta. Report No. 6, Uni. of Wash., 1950.
21. PIERCE, R. E., and GEORGE, E. E., "Economics of Long Distance Energy Transmission," *Trans., AIEE.*, T.P. 48-195, Vol. 67 (1948).
22. FIES, M. H., "Progress Report on 2nd Experiment in Underground Coal Gasification," *Power Engineering*, May, 1950.
23. U.S. Bureau of Mines Information Circular No. 7490, February, 1949.
24. LOUTTIT, J. E., "Fireless Cooking Makes Smokeless Fuel and By-Products at 20-Ton Plant, Tacoma, Washington," *Coal Age*, Vol. 42, No. 4 (1937), pp. 155-57.
25. *Low Temperature Carbonization of Utah Coals*, Utah Conservation and Research Foundation, Quality Press, 1939.
26. U.S. Bureau of Mines, Region IV, Advance Release, "New Process Obtains Tar and Low-Cost Power from Coal," August 3, 1951.
27. HOGUE, F. T., "Gas Turbines in Stationary Power Generation," *Electrical Engineering*, October, 1949, p. 855.
28. "Annapolis Gas Turbine Operates Successfully at 1500° F," *Power Generation*, February, 1950, p. 67.
29. MONTELL, R. R., "The Northwest Power Problem and Washington Coal," Report to the Coal Producers Association, December, 1949, Chap. 5, p. 18.
30. "Electric Utility Cost Units of Steam Electric Generating Stations," Federal Power Commission, F.P.C. S-68, 1948, p. 11.
31. "Utility Depreciation Practices," Federal Power Commission, F.P.C. S-87, 1949, p. 17, table 9.
32. "Electric Utility Cost Units of Hydroelectric Generating Stations," Federal Power Commission, F.P.C. S-78, 1948, p. 11.


## UNIVERSITY ENGINEERS ON SCIENCE PROGRAM

At the meeting of the Northwest Scientific Association held in Spokane, December 27-28, F. B. Farquharson, Director of the Engineering Experiment Station presided as chairman of the Engineering Division. Appearing on the program from the Department of Chemical Engineering were Dr. R. W. Moulton with a paper on "Gasification of the Bituminous Coals of Washington," and Dr. J. L. McCarthy, co-author with W. W. Koenig, graduate student, of "Continuous Absorption and Separation of Metal Ions by Means of Moving Ion-Exchange Resin Beds."

Dr. Piotr Zenczak, Assistant Research Wood Technologist, read a paper on "Lignin Complex and Its Extraction from Wood with Triethylene Glycol," and J. H. Bigford, Acting Instructor in Mechanical Engineering spoke on "Solar Heat for Future Homes."

# Lignite Process Hits the Mark*

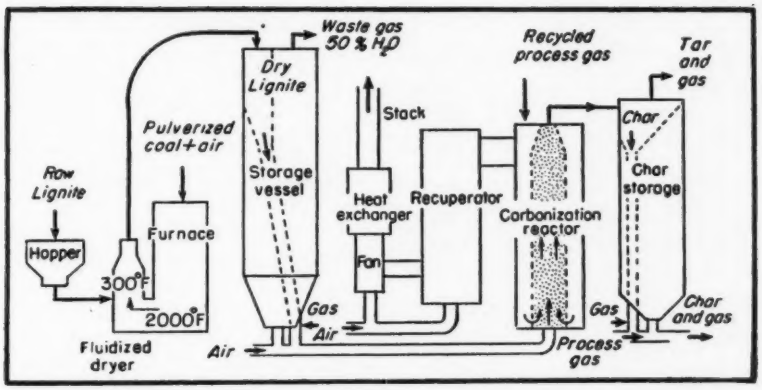



DIAGRAM SHOWING MAJOR OPERATING UNITS OF COMMERCIAL PROCESSING PLANT TO HANDLE 7,000 TONS OF LIGNITE DAILY

THIS LATEST TECHNIQUE in the low-temperature carbonization of coal—now to be commercialized after two years of research work—already has the earmarks of a development that may very well affect the future economy of many industries and of wide areas. That seems to be the general—but not the unanimous—opinion of chemical engineers, power men, coal processors and light-metals authorities throughout the country.

The new process, developed by the Bureau of Mines at its Denver laboratories, uses lignite and other low-rank non-coking coals to turn out crude coal tar and a high-heating char ideal for power plant use. It hinges on the principles of fluidized drying and low-temperature carbonization.

First commercial plant to use the process will be at Aluminum Co. of America's reduction works to go up in Milam County, Texas, near Waco. There a battery of lignite processing units will provide solid fuel for the steam-driven power generating facilities that Texas Light & Power Co. will build and operate for Alcoa. TL&P cooperated with the Bureau of Mines in developing the process.

In the new Texas plant, slated to go on stream in the fall of 1952, close to 7,000 tons of lignite will be processed daily into some 3,200 tons of char and 2,300 bbl. of tar. Cost of the twelve 575-ton-a-day units will be close to $9 million. . . .

**Its Impact**

Economic impact of BM's new development—generally known as the Parry process—may eventually spread out into many fields and geographic areas:

Most significant, by far, are its long-range possibilities in opening up the nation's vast and largely unexploited reserves of lignite and other low-rank non-coking coals. These deposits are scattered throughout the West and Southwest. Reserves of lignite in Texas' Milam County alone easily top 100 million tons. There's even more in such states as Montana and North Dakota.

". . . applicable to any coal of lesser rank than high volatile bituminous B—and that means 90 percent of all western coals . . ." says V. F. Parry, chief of BM's Denver coal branch laboratories and the man who supervised the development of the process.

Most immediate impact will probably be in the power generating field. Here it is significant to remember this: Alcoa and Texas Power & Light, both veterans in figuring out the fine points of energy economics, are willing to jump in on a large scale early in the game. And in Texas, too, deep in the heart of natural gas' undisputed bailiwick.

". . . this process offers a great opportunity to thermal power plant operators throughout the West." Parry adds, ". . . and (its char) can compete with natural gas as a fuel." He estimates that byproduct tar recovery would put Milam County lignite char

* Reprinted by permission of *Chemical Engineering* from the issue of September, 1951, pp. 219-222.

on a par with natural gas selling at 5–8 c. per 1,000 cu. ft. Cost of mining the lignite is said to be only $1.00-$1.50 per ton.

By using lignite char to fuel its power generating plant, Alcoa may be able to get its energy for aluminum reduction at about 3.5 mills per kwh. Credit from tar and oil byproducts might shave this to 2.5 mills.

Raw lignite—with some 35 percent moisture—has a heating value of 7,000 Btu. per lb. The bone-dry processed char has a value of 10,600 Btu. per lb. Thus the char has only 45 percent of the raw lignite weight but retains 75 percent of the heating value—an obvious shipping advantage.

Lignite's place in our coal-tar chemical economy is not yet so clear-cut. Some non-coking coals that can be processed by the Parry method will yield up to 45-55 gal. of tar oil per ton. Big question seems to be: what's the tar and oil worth on today's market, what will tomorrow's markets be?

". . . tar recovered from an average western coal will have a value of at least 8–10 c. per gal.—equal to the value of the raw coal," Parry says, ". . . indicating processing costs of the tar oil are relatively nominal." Milam County lignite is expected to yield 14 gal. of tar per ton.

Alcoa evidently plans to use its 2,300 bbl. daily of crude tar as a fuel or to sell (or refine) it, depending on economic and market factors. The tar has a fuel value of some 4–5 c. per gal.

Later, of course, lignite tars may find their market niche as feed stocks for conversion into aromatics such as benzene, toluene and xylenes. Light naphthas can be distilled off for use as a gasoline blending agent. Tar acids can be extracted by standard coal-tar processes.

The process, Parry says, can be used to produce liquid fuels in two ways: (1) by hydrogenating its tar oils, using relatively little hydrogen, to turn out quality synthetic liquid fuels ranging from heavy industrial fuel oil to aviation gasoline; (2) by using its carbonizing equipment to extract oil from shale fines that now have to be discarded. . . .

He is convinced the West can get its lowest-cost power by processing non-coking coals and by integrating this power production with the manufacture of synthetic liquid fuels ". . . because of the advantages in extracting the tar before burning the charred residues for power."

**How Process Works**

Heart of the Parry process lies in two unit operations: (1) fluidized drying of the crushed raw lignite; (2) low-temperature carbonization of the dried lignite to produce tar and char.

The process is not designed to handle coking coals; fuels with weak coking properties have been carbonized successfully in the Bureau's 5- and 25-ton-a-day pilot plants at Denver. The method has been under development for close to two years. It was worked out as a cooperative project between the Bureau of Mines and Texas Power & Light Co.

BM has designed for Texas Power & Light a 575-ton lignite processing unit patterned after its own pilot plants. Here are the major operating features (*see cut*) of a commercial plant (excluding tar- and gas-scrubbing units) as Parry described it to *Chemical Engineering:*

Lignite crushed to pass 0.25 in. is fed into a stream of combustion products that are generated by burning pulverized lignite under pressure. The sensible heat in the combustion gases at 2,000 deg. F. is transferred to the raw lignite to evaporate its moisture and to raise the temperature of the mixture to about 300 deg. F. This is done in a fluidized or entrained bed just above the screw feed.

The mixture moves upward to dust separators in the upper part of the storage vessel. Moisture and waste products leave through the stack. The hot, dried lignite moves down the conduit to feeders that regulate the flow to the carbonizer. Treatment time in the fluid bed is about 30 sec.

Hot, dried dust from the sprayer is conveyed pneumatically to the base of the carbonizing reactor—a heat-resisting alloy cylinder mounted in a furnace setting that burns process gas around the cylinder. Hot gases from the combustion zone pass through recuperators and heat exchangers to preheat the ingoing air and gases.

Clean process gas, generated during the carbonization, is recirculated to the base of the reactor by passing downward through an annular space next to the heated walls. This hot gas enters the center of the chamber and carries the fine coal upward in a fluidized state.

Air entering with the preheated coal combines with the gas and char to liberate heat at the desired temperature. The temperature of the fluidized mass inside the reactor is maintained by passing heat through the walls of the retort and by combustion of the air and char. The temperature is regulated by adjusting the rate of coal and air fed to the bottom of the reactor.

Carbonization can be carried out at any temperature. Optimum is close to 900 deg. F. for producing maximum tar and enough gas to supply heat for carbonization with enough excess to transport the char to the power plant burners. There it is burned in the usual manner in the combustion chamber of the boilers.

*(Continued on page 32)*

# Fish-Tag Tests Favor New Design

DAYTON L. ALVERSON
*Fishery Engineer, U.S. Fish and Wildlife Service*

HARRY H. CHENOWETH
*Assistant Professor of Civil Engineering*

FIG. 1. MR. ALVARSON PLACING TAGGED FISH IN CHANNEL
*Photo by* BUCHANAN, Seattle

DESPITE LARGE SUMS OF MONEY spent in efforts to tag tuna, no tags have been recovered. Tags that hold on salmon and other fish will not hold on tuna. Examination of a tuna shows that he is built for speed. In addition to his generally streamlined shape, his fins can be either retracted or folded into recesses along his body. Upon being released in a tank, an uninjured tuna will often take off with such a burst of power that his head will be mashed against the end of the tank. Although no tagged tuna have been recovered, some tuna have been caught that show evidence of having been tagged. The U. S. Fish and Wildlife Service recently did some work at the University of Washington on the development of better tags for tuna.*

* See "Experimental Testing of Fish Tags on Albacore in a Water Tunnel," by Dayton L. Alvarson and Harry H. Chenoweth, *Commercial Fisheries Review*, August, 1951.

A water tunnel, installed at the Charles W. Harris Hydraulics Laboratory, was essentially a 5-foot-long box (8 inches wide and 10 inches deep) with steel channel sides and clear lucite plates top and bottom. Along the sides, teak wood was designed in a fusiform pattern to keep the distribution of water velocity past the fish nearly constant by maintaining the net flow area approximately equal. The entrance of the tunnel section was well rounded to eliminate eddy currents, and the kinetic energy in this section was partially recovered by an expander section downstream from the tunnel. Water was obtained from Frosh Pond on the campus, a one-acre holding pond. The 95-foot available head gave velocities up to 28 mph along the fish. Velocities were determined by means of a differential mercury gage and computed velocities were verified by draw-down tests on

H. H. Chenoweth

a large steel tank located in a wing of the Health Sciences Building.

Fish, obtained from cold storage, were drilled fore and aft for fish holders, transverse rods through the body; the ends of the rods were carried in sockets on each side of the tunnel. Tags of different designs were then selected and arranged on the fish in appropriate positions. In preparing an albacore for the tunnel, sufficient thawing occurred so that tags could be easily inserted in the fish; however, the interior portion remained frozen, holding the fish in position against the water flow. The fish was then arranged in the tunnel (Fig. 1), the lucite coverplate bolted in position, the mercury gage freed of air bubbles, and the valve controlling the water flow was opened slowly until the mercury reading corresponded to the desired velocity. Results of the experiment were then observed through the lucite plates. The water velocity and the length of time it took to tear out the various type tags were recorded. From this record and the observed action of the water on the tags, an opinion as to the merits of each tag was formed.

Several limiting factors made it necessary to conduct each test for only a short period. The fish would thaw rapidly in the water and become difficult to hold at high velocities; and bruises to the fish received during landings or storage would open up under these high water velocities and result in the water forcing portions of the skin from the fish. The trials lasted from 6 to 14 minutes, the average being approximately 10 minutes. The general procedure was to increase the velocities at fixed intervals throughout the test until the tags were either dislodged or the fish showed signs of tearing loose from the holders. If the tags were not torn from the fish during the trial, the coverplate was removed and the condition of the tag and its effect on the fish was noted.

The following types of tags were tested (Fig. 2):

1. Peterson tag (Rounsefell and Kask, 1943). (See Fig. 2-a.) Tags of both 8 mm and 14.5 mm diameter were tested, placed in four different positions.
2. Plastic strip tag, an adaptation of an internal body tag (not shown in figure).
3. Strap or cattle tag (Fig. 2-b and -c).
4. Hook tag. This tag, used in albacore studies by the Fisheries Research Board of Canada, is 6 cm long and made of nickel wire (Fig. 2-d). Nine trials were made with a tag similar to that shown in the illustration but having the identification stamped on an attached flat plate.
5. Streamer tags.
   *a*) Plate 9 mm x 15 mm secured to fish by a nylon line. This tag was developed by the Oregon Fish Commission (Fig. 2-e).
   *b*) Torpedo-shaped plastic cylinder secured with nylon line (Fig. 2-f).
   *c*) Tag developed by the senior author (Fig. 2-g). Flexible plastic streamer 8 mm x 34 mm and less than 1 mm thick, attached by braided nylon thread. Seven trials were made.

A number of factors involved in these experiments allowed variations from conditions which would exist in nature. The texture or consistency of the thawed fish to resist deformation would not be equal to that of a live albacore. The sides of the tunnel undoubtedly caused a certain amount of back turbulence; also the distribution of velocity along the body of the fish would vary slightly because of the changing area of flow. The muscular actions of live fish were also lacking. The experiments were conducted only for short periods, and tags would likely be dislodged at velocities lower than those experimentally determined when subject to the same forces over a longer period of time.

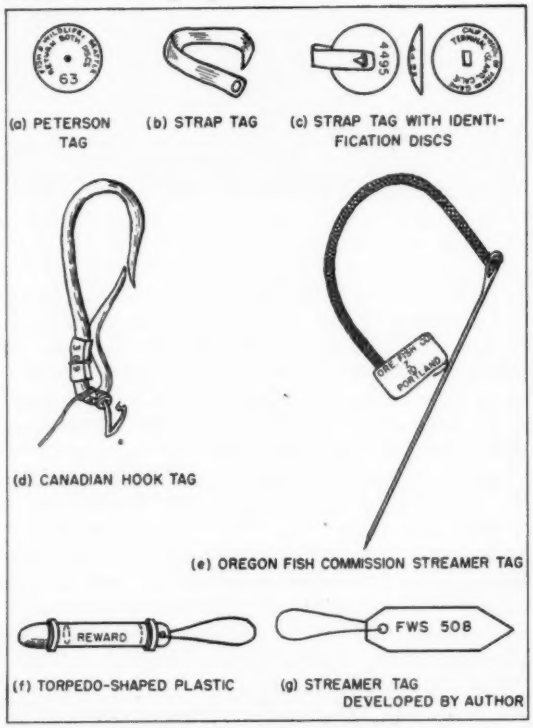



FIG. 2. TYPES OF TAGS TESTED ON ALBACORE

Despite these limitations, the tests indicated that the use of Peterson-type tags or any other tag which offers considerable resistance to the water flow will probably result in failure when used on a fish which swims at high speeds. The plastic strip tags held in all tests and from the hydraulic standpoint should be satisfactory. Strap tags such as used in the California mackerel fishery could not be dislodged, but tests made in the water tunnel indicated that these tags would gradually work free. Hook tags developed by the Fisheries Research Board of Canada were not dislodged but resulted in injury to the jaw of the fish. This tag is still in the experimental stage and modifications could partially eliminate these faults. Reduction in the shank size and stamping the identification on the shank as shown in Fig. 2-d, instead of on an attached plate, would reduce drag.

From the experimental results, it appears that the streamer tags (among those tested) offer the greatest chance of developing successful external tagging operations for tuna-like fish.

The tag developed by the senior author was tested at maximum velocities and remained fixed throughout the trials.

Tuna runs off the Pacific Coast were tagged this season with tags developed as a result of this research. Unfortunately the tuna runs during the tagging operations were unusually small. Whether or not the new tags will remain on the fish is something only time will tell.

---

# Nonlinear Servomechanism Research Under Way

Research on nonlinear servomechanisms has been started in the Department of Electrical Engineering, under a contract with the Office of Naval Research. The project, supervised by T. M. Stout, Instructor in Electrical Engineering, will require use of equipment in the Servomechanism Laboratory and the electronic analog computer built under Engineering Experiment Station sponsorship. Research fellows Melvin H. Eklund and Chinubhai N. Shah have been assigned to the project.

Despite analytical difficulties, investigators have made some progress in dealing with unintentional nonlinearities in servomechanisms, such as gear backlash or motor torque saturation. In addition, some work has recently been done on the deliberate use of nonlinearity, suggested as a means of improving servomechanism performance which is temporarily limited by the capabilities of currently available components. This project is particularly concerned with the optimum design of deliberately nonlinear servomechanisms and seeks to determine what kinds and amounts of nonlinearity are desirable.

In linear systems, the response to an abrupt input change can be used to predict the response to a sinusoidal input, and conversely, so that either test is adequate for design purposes. Moreover, the character of the response is independent of the size of the input. In nonlinear systems, however, a new calculation must be made for each kind and size of input. Because designers are anxious to avoid these calculations, which are tedious for even relatively simple systems, two fundamental questions will be investigated: How can computers be used in the determination of the best system parameters? Is the response to a single input an adequate basis for the design of nonlinear systems?

"Optimum design" for linear systems has frequently been based on the criterion of minimum mean-square-error for a given input. A preliminary investigation has shown that direct measurement of the mean-square-error or mean-absolute-error, using an analog computer and suitable meters, forms a satisfactory experimental procedure for the design of linear systems. This procedure gives the designer an objective measure of system performance and, if applicable, should permit useful comparisons of various nonlinear systems.

Whether an optimum design for one type of input is also optimum for other inputs will be studied. If this proves to be the case, consideration of a single input will be sufficient; if not, the proposed experimental procedure will be helpful in determining a design which is a satisfactory compromise. In either case, correlation of the responses of nonlinear systems for various inputs should simplify design.

The analog computer to be used is an "electronic differential analyzer" and utilizes feedback amplifiers to add, subtract, integrate, differentiate, or to multiply variables by constant numerical coefficients. Another unit will furnish the product of two variables and may also be used as an arbitrary function generator.

In addition to uncovering specific techniques for design of nonlinear servomechanisms, the research is expected to result in a better understanding of the behavior of nonlinear dynamic systems.

## ABOUT OLIVINE

THE OLIVINE in the Twin Sisters' region of Washington, the largest known single deposit in the United States, is mostly unaltered dunite, a magnesium and iron orthosilicate generally containing about 50 per cent magnesium, 40 per cent silica, and 10 per cent ferrous oxide. It is transparent or translucent, and its color may vary from light to deep shades of green and yellow, gray, brown, and red, or it may be almost colorless. It generally occurs as small rounded glassy grains or in granular aggregates or rounded loose pebbles, and it is characterized by many wide cracks filled with some alteration product. Its hardness is 6.5 to 7 (Moh), between feldspar and quartz, and its specific gravity, depending on its iron content, varies approximately from 3.2 to 3.6.

The ancients of 3,000 years ago, who knew olivine as a gem stone, called it chrysolite (gold stone), and imported it chiefly from an island in the Red Sea. Through the ages its use was confined to the gem industry, and only in the present century have scientists considered widening its industrial horizon. In the 1920's discovery of olivine's promising refractory properties led to a series of patents in the United States, Great Britain, Canada, France, and Germany, covering its use in ceramic, refractory, and building material of various formulas. Chief among the first patentees of "gold stone" was, appropriately, Dr. Victor M. Goldschmidt of the University of Oslo, who has continued to hold the greater number of olivine patents in all of these countries. Actual commercial use was first developed in Germany from 1928 to 1931. Since 1933 the Harbison-Walker Company of Pittsburgh has owned the sole American rights to the Goldschmidt process of making "Forsterite" brick.

At the University of Washington, interest in the possible uses of the huge olivine deposits in the state prompted, in 1934, the initiation of an 8-year cooperative research program undertaken by the School of Mines (then the College of Mines) and the Northwest Experiment Station of the U. S. Bureau of Mines. During this period, under the direction of Professor Hewitt Wilson of the School of Mines, and Dr. H. F. Yancey of the Bureau of Mines, investigations were directed chiefly toward the refractory properties of the Washington olivine, but some work was done on its use as a foundry sand, and several other directions of future study were pointed out. As a result of the work done on this program eight Master's theses were written. Recently Dr. P. D. Johnson, and at present Dr. James I. Mueller of the Department of Ceramic Engineering of the School of Mines have directed studies on the use of olivine in ceramic bodies for manufacturing tile and dinnerware.

In the Department of Chemical Engineering under Dr. R. W. Moulton, the problem of obtaining magnesium from olivine has been considered, and suggestions for mixing olivine with phosphate rock for use a a fertilizer have been actually put into commercial practice on a small scale. (See *The Trend* for January, 1950.) Within the past two years in the Department of Mechanical Engineering, Professor G. S. Schaller has directed graduate research on olivine as a foundry molding sand, resulting in publication of several articles.

Perhaps continued efforts will solve the problem of how to dispose of Washington's mountains of olivine to the best advantage of the state and nation.

# Olivine Qualifies for Ceramic Uses

A research report on olivine as a constituent in dinnerware and wall-tile bodies was read by one of the authors, Professor James L. Mueller at the Pacific Coast regional meeting of the American Ceramic Society, October 25, at Long Beach, California. Co-authors were Professor P. D. Johnson and graduate student James E. Dore, whose work for his M.S. in Ceramic Engineering was sponsored by the Edward Orton, Jr., Ceramic Foundation.

In the past the ceramic industry has been the largest user of olivine, but they have utilized only its refractory characteristics. In this investigation, the ceramic engineers made use of olivine's ability to lower the melting point of other materials present, thus forming a dense wear-resistant mass at a relatively low temperature.

Professor Mueller revealed that the research was encouraging and that certain of the mixtures meet existing specifications for wall tile, earthenware, and semi-vitreous dinnerware.

The chief objection to the manufacture of ceramic ware using olivine, is that the color of the fired piece ranges from salmon pink through tan-pink to light brown, whereas most manufacturers desire a pure white. Professor Mueller emphasized that this objection can be overcome by using an opaque glaze or one that will mask out the color of the body. However, in some cases, the texture and color of the fired body lend themselves to the newer trends in dinnerware design, so that use of a transparent glaze which reveals the fired body may be not only quite acceptable but also desirable.

The Ceramic Engineering Department since 1934 has conducted various research projects on olivine of which some four and a half million tons are available in this state. The largest share of this is located in the Twin Sisters area of the Cascades.

Olivine research, sponsored by the Edward Orton, Jr., Fund, is being continued this year under the direction of Professor Mueller.

# OLIVINE AS A SOURCE OF MAGNESIUM*

NORMAN KETZLACH
*Research Fellow in Chemical Engineering*

R. W. MOULTON
*Professor of Chemical Engineering*

N. Ketzlach

## Introduction

Of all the sources of magnesium in the state of Washington, the largest is olivine. The mineral olivine, though known to mineralogists for many years, was of little commercial value in the United States before 1933; its refractory properties first attracted commercial attention.

The two largest deposits of olivine in Washington are found in the Twin Sisters mountain region, about 10 miles southwest of Mount Baker and approximately 80 miles north of Seattle, and on the southeast corner of Cypress Island about 80 miles northwest of Seattle. Olivine occurs in the Twin Sisters area as an elliptical mass 10 miles long by five or six miles wide and at elevations of 3,000 to 6,000 feet above sea level. This is the largest and least altered body of its kind known in the United States. Alteration of the Twin Sisters olivine is confined to weathering; there is no evidence of serpentinization. Cypress Island olivine forms a symmetrical dome, called "Olivine Hill," at the southeast end of the island, which rises to about 600 feet at the center and covers an area of about one-half by two-thirds of a mile. A large portion of this olivine has been altered by weathering and serpentinization. The importance of this deposit lies in its large tonnage of refractory olivine at tide-water.

The other large known deposits of olivine in the United States are in North Carolina and Georgia; another one is located in Grant County, Oregon, but its extent and quality are not known.

It has been estimated that twelve million pounds of metal can be produced annually for the next fifty years from the recently discovered 68-acre deposit of olivine in Georgia. In the Pacific Northwest the Twin Sisters deposit of 25,600 acres could yield nearly 377 times that figure, or 450 million pounds of metal annually over the next 500 years, in addition to the Cypress Island deposit estimated at 50 million tons of olivine.

R. W. Moulton

Early technical reports in general state that the cost of processing silicates is an economic barrier to their utilization, especially where more reactive minerals, such as carbonates, oxides, or salts are available. This objection is not entirely justified in the case of olivine. Unlike most silicates, olivine is most readily attacked by acids, chlorines, and other reagents without resorting to fusion to break down the silicate structure. Moreover, with a magnesium content within tenths of a percent of that of the best magnesite, and with so enormous a deposit available, a process for recovering metallic magnesium from this mineral should be developed.

## Possibilities of Olivine as a Source of Magnesium

As stated previously, the principal uses for olivine have been in the refractory fields, and much of the experimental work with olivine has been in that field.[1,2] More recently olivine has also been considered as a raw material for a fertilizer[3] by fusing the ore with phosphate rock. A small plant built near Webster, North Carolina[4] for making epsom salt from olivine by treatment with sulphuric acid is now in commercial operation. A number of methods have been worked out for the production of magnesium,[5,6,7,8,9] but none of them are satisfactory.

Chemical analysis of olivine samples from widely scattered localities show an unexpected uniformity in magnesium content which ranges from 27 to 30 per cent. A further advantage is the low calcium content of the ore, which eliminates the necessity of separating calcium from magnesium. This separation can often be a considerable item of expense in processing minerals containing magnesium. Calcium is entirely

*Condensed by N. R. Mukherjee from the thesis submitted by Norman Ketzlach for the degree of M.S. in Ch.E., 1944. The study was carried on under the supervision of Dr. Moulton.

## TABLE I

### RESULTS OF TYPICAL LEACHING RUNS

(Ore roasted 5 hr at 700° C)

3N HCl leach
100% excess acid
Temp of leaching: 60° C

| Time (Min.) | Yield (%) | | |
|---|---|---|---|
| | MgO | $SiO_2$ | $Fe_2O_3+Al_2O_3$ |
| 15 | 5 | 4 | .... |
| 30 | 14.5 | 16.2 | 3.8 |
| 60 | 28.3 | 24.5 | 8.3 |
| 100 | 31.0 | 32.4 | 19.3 |

3N HCl leach
120 g $NH_4Cl$; theoretical amount of acid
Temp of leaching: 70° C

| Time (Min.) | Yield (%) | | |
|---|---|---|---|
| | MgO | $SiO_2$ | $Fe_2O_3+Al_2O_3$ |
| 25 | 17 | 12.9 | 22 |
| 60 | 52 | 14.0 | 52 |
| 100 | 72.5 | 8.0 | 71 |

61.2 g $NH_4Cl$
6N HCl leach
100% excess acid
Temp of leaching: 60° C

| Time (Min.) | Yield (%) | | |
|---|---|---|---|
| | MgO | $SiO_2$ | $Fe_2O_3+Al_2O_3$ |
| 30 | 27.2 | 15.7 | 20.4 |
| 90 | 30.7 | .... | 30.6 |
| 180 | 33.0 | .... | 34.5 |

75.7 g $(NH_4)_2SO_4$
6N $H_2SO_4$ leach
100% excess acid
Temp of leaching: 60° C

| Time (Min.) | Yield (%) | | |
|---|---|---|---|
| | MgO | $SiO_2$ | $Fe_2O_3+Al_2O_3$ |
| 30 | 30 | 22.5 | 24.0 |
| 90 | 40.5 | 27.4 | 44.1 |
| 180 | 25.8 | .... | 45.5 |

61.2 g $NH_4Cl$
3N HCl leach
100% excess acid
Temp of leaching: 65° C

| Time (Min.) | Yield (%) | | |
|---|---|---|---|
| | MgO | $SiO_2$ | $Fe_2O_3+Al_2O_3$ |
| 30 | 38.1 | 27 | 42 |
| 95 | 70.0 | 34 | 76 |
| 180 | 95.0 | 6 | 89.2 |

75.5 g $(NH_4)_2SO_4$
3N $H_2SO_4$ leach
100% excess acid
Temp of leaching: 65° C

| Time (Min.) | Yield (%) | | |
|---|---|---|---|
| | MgO | $SiO_2$ | $Fe_2O_3+Al_2O_3$ |
| 30 | 29.0 | 11.6 | 41.1 |
| 95 | 62.5 | 27.5 | 87.0 |
| 180 | 91.0 | 37.0 | 100.1 |

39.5 g $CaCl_2$
3N HCl leach
50% theoretical acid
Temp of leaching: 55° C

| Time (Min.) | Yield (%) | | |
|---|---|---|---|
| | MgO | $SiO_2$ | $Fe_2O_3+Al_2O_3$ |
| 40 | 34.6 | 19.1 | 28 |
| 50 | 32.5 | 7.8 | 29.4 |
| 140 | 64.7 | 1.0 | 59.5 |

78.9 g $CaCl_2$
pH 2 leach
Temp of leaching: 55° C

| Time (Min.) | Yield (%) | | |
|---|---|---|---|
| | MgO | $SiO_2$ | $Fe_2O_3+Al_2O_3$ |
| 40 | 4.3 | 3.0 | 5.4 |
| 140 | 5.7 | 6.2 | 9.1 |
| 480 | 19.5 | 0.8 | 18.3 |

absent from many samples and seldom exceeds 0.1 per cent.

The major impurities from the viewpoint of magnesium production are iron and silica. Minor impurities consisting of chromite, nickel silicate, manganese oxides, and aluminum, some of which are potential by-products, can be removed by simple methods or may remain to advantage if magnesium is to be used for certain alloys. The analysis of a representative sample of olivine from the Twin Sisters deposits is as follows:

MgO, 48.9 per cent; $SiO_2$, 41.7 per cent; $Fe_2O_3$ and $Al_2O_3$, 10.0 per cent; ignition loss 0.49 per cent.

TABLE II

RESULTS OF TYPICAL REDUCTION RUNS

| Run No. | Mesh Size | Time (hr) | | Temp (°C) | Press. (mm) | Yield (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | Total | At Max Temp | | | $SiO_2$ | $R_2O_3$ | MgO |
| 1 | 100-150 | 8 | 5 | 950 | 9.0 | .... | .... | 7.0 |
| 2 | 150-200 | 9 | 5.5 | 930 | 3.5 | .... | .... | 11.9 |
| 3 | 150-200 | 9 | 8 | 625 | 0.5 | .... | .... | 2.4 |
| 4 | 100-150 | 6.5 | 4 | 800 | 2.0 | .... | .... | 1.7 |
| 5 | 150-299 | 9 | 6 | 990 | 0.5 | 2.48 | 3.2 | 43.5 |
| 6 | 150-200 | 12 | 9 | 950 | 0.5 | 1.61 | 19.6 | 34.0 |
| 7 | 150-200 | 11 | 10 | 850 | 0.4 | 5.65 | 24.2 | 4.2 |
| 8 | 200-500 | 13 | 4.5 | 950 | 0.4 | 0.67 | 22.2 | 30.5 |

**Experimental Work**

The laboratory work can be divided into leaching runs and reduction runs. All the leaching runs except the ones using calcium chloride and the hydrochloric acid-ammonium chloride run, were made with Cypress Island olivine obtained from the Bureau of Mines. The remaining leaching runs, as well as the reduction runs, were made with ore obtained from the Twin Sisters deposit (Tables I and II).

***Leaching Treatment.*** The heat treatments with ammonium chloride and ammonium sulphate were followed by water leaches. All of them gave very low yield of magnesium in solution.

The ore roast was followed by a leaching treatment with different kinds of reagents, such as hydrochloric acid, hydrochloric acid-ammonium chloride, sulphuric acid-ammonium sulphate, at different temperatures. The results are given in Table I.

***Reduction Treatments.*** The reduction of olivine by calcium carbide seemed most promising from the thermodynamic calculations. The bomb used for the reaction was made from a 2-in. iron pipe (standard stainless steel pipe) 5 in. long. The bomb was heated with electric combustion furnace. The top flange of the bomb was insulated from the atmosphere with magnesia. One of the outlets leading from the bomb led to a vacuum manometer and a McLeod gage connected in parallel. The other outlet went to a vacuum pump. Some glass wool was inserted in each of the two outlets to prevent the fine charge from getting into the gages and vacuum pump.

The charge for all the runs consisted of 32.6 g of calcium carbide mixed with 25 g of ore. In all cases the ore and calcium carbide were of the same mesh. The calcium carbide used contained 70 per cent calcium carbide on the basis of the acetylene generated.

The material that went into the manometer tube and into the tube leading to the vacuum pump was analyzed for ($Fe_2O_3$+$Al_2O_3$), calcium, and magnesium. The residues were analyzed for $SiO_2$, ($Fe_2O_3$+$Al_2O_3$), calcium, and magnesium. The results are tabulated in Table II.

Great care was taken in analyzing the residues so as to prevent the unreacted charge from going into solution. Therefore the residues of the first four runs were digested with ammonium chloride at a pH of 8. The resulting solution yielded very little magnesium. Since all the residues were black, indicating carbon, some reaction must have taken place. Therefore, the residues, after digestion, were placed in a muffle furnace (800-900° C) to burn off the carbon. The resulting residues contained a number of white particles dispersed through them. These were probably either magnesium oxide or calcium oxide, indicating poor recovery during digestion.

Some blanks were then made up with olivine and solutions of different pH (pH 6, 4, 2, and 1 normal). Upon standing two days, the solutions of pH 6 and 4 gave no qualitative test for magnesium. The solution of pH 2 gave a very weak test for magnesium while the 1 normal solution gave a very positive test. On the basis of these blanks, the baked residues were leached at a pH of 2-4 for one-half hour. The results in Table II were based on the analysis of these solutions.

Four more runs were made leaching the residues at pH 2-4 for two hours. A blank was also run with olivine and metallic magnesium by leaching for two hours at pH 2-4. Very little magnesium and iron went into solution. In the tabulation of results, corrections for the blank run were made for the last four runs. Corrections were not made for the first four because they were analyzed under somewhat different conditions.

The samples taken from the tubes leading to the manometers and the vacuum pump were analyzed in a similar manner and yielded magnesium of the order of one per cent.

From the laboratory work done on the ferrosilicon process[10] an optimum yield of 85 per cent was ob-

TABLE III

RELATIONSHIP OF IRON YIELD TO MAGNESIUM YIELD

| Run No. | Temp (°C) | Yield (%) | |
|---|---|---|---|
| | | Mg | Fe |
| 5 | 990 | 43.5 | 3.2 |
| 6 | 950 | 34.0 | 19.6 |
| 8 | 950 | 30.5 | 22.2 |
| 7 | 850 | 4.23 | 24.2 |

tained in 8 hours at a temperature of 1165° C and about 0.6 mm pressure. This low pressure was used since very poor yields were obtained above one mm pressure. Temperature was also shown to have a marked effect, very low yields being obtained below 900° C and about a 90 per cent yield at 1165° C.

Table III is of interest, showing that as the per cent of available magnesium, as analyzed in the residue, increases, the per cent yield of available iron decreases. The fact that the per cent of magnesium increased with the temperature must be considered in the light of other variables in these data, namely, time and size of the material used. The decreasing yield of available iron with increasing temperature seems unexpected. However, in view of the fact that the free energy for the reaction between ferrous silicate and calcium carbide is more negative than that for magnesium silicate, it seems to indicate that iron would be formed more readily than magnesium. Moreover, with increase in temperature there should be more iron. However, this iron formed could very possibly have reacted with the carbon, one of the products of the calcium carbide reduction reaction, forming iron carbide. The formation of the iron carbide from its elements is an endothermic reaction and by the Law of Le Chatelier should take place more rapidly with an increase in temperature. This iron carbide reacts with water, giving methane, hydrogen, and probably an oxide of iron which would be insoluble under the leaching conditions used. On the other hand, metallic iron would be soluble.


**Summary**

1. Olivine may be leached with HCl and $NH_4Cl$ or $CaCl_2$ and acid to give a solution containing a much higher per cent magnesium than is found in original olivine ore. Digestion of the ore with acid only, on the other hand, gives a solution no richer in magnesium than that found in the original ore. Sulfuric acid and $(NH_4)_2SO_4$, although giving a solution a little richer in magnesium than found in the original ore, is not as good a leaching reagent as HCl and $NH_4Cl$.
2. Calcium carbide was found to be a reducing agent for olivine.
3. Using calcium carbide as the reducing agent, the yield was found to increase with an increase in temperature. There is a very marked increase in yield between 850 and 950° C, very low yields being obtained below 850° C.
4. Using calcium carbide as the reducing agent, the yield was found to increase with increase in fineness of the charge. The difference in yield between a charge of 150-200 mesh and that of a 200-500 mesh is very marked.
5. Using calcium carbide as the reducing agent, the yield was found to increase with increase in time. As no optimum yield was obtained with increase in temperature, higher temperatures should be tried.


**REFERENCES**


1. GOLDSCHMIDT, V. M., *Ind. Eng. Chem.* **30**, 32 (1936).
2. HUNTER, D., North Carolina Dept. Conserv. Develop. Bull. No. 41 (1941).
3. WALTHALL, J. H., and BRIDGER, G. L., *Ind. Eng. Chem.* **35**, 774 (1943).
4. PAMEL, G. N., *Min. Met.* **23**, 331 (1942).
5. GLENN, D., "The Rankin Process for the Production of Magnesium Metal from Olivine and Other Magnesium Bearing Ore," personal communication.
6. HOUSTON, E. C., and RANKIN, H. S., Am. Inst. Min. Met. Engrs. Tech. Pub. No. 1484 (1942).
7. LUBKER, R. A., "The Extraction of Magnesium from Olivine," Thesis, University of Washington, 1942.
8. WILSON, P. D., *Mining Met.* **23**, 201 (1942).
9. SUNDSTROM, R., unpublished data, 1943.
10. BAGLEY, G. D., *Ind. Eng. Chem. News Edn.* **22**, No. 11, pp. 921, 958.


---

***"When this country entered World War I it so happened that a leading professor of chemistry was a relative of the then Secretary of War. Taking advantage of that fact he called on him in the first week after war was declared to offer on behalf of the American chemists the services of the profession to aid in the war effort. The Secretary said he would look into the matter and asked his caller to return a day later. When he did so the Secretary of War thanked him once again for his offer of assistance, asked him to transmit the thanks to his fellow chemists, but said it would be unnecessary to accept the proffered assistance because on looking into the matter he found the War Department* had *a chemist."***

—James B. Conant in his address before the Jubilee Meeting of the American Chemical Society. *Chemical and Engineering News*, Sept., 1951.

# MOISTURE CONDENSATION ON ENCLOSED SHOW WINDOWS*

THEODORE L. GERSHUN
*Instructor in Mechanical Engineering*

T. L. Gershun

The problem of moisture condensation on windows is one which has been encountered in business places for many years. Numerous solutions for the problem have been offered, some of which have been practical and many more impractical.

In this study of the problem of moisture condensation on show windows, the investigation was devoted to closed display areas in retail stores. Trends at the present time, however, particularly with respect to suburban localities, are toward show windows which do not have a closed display area. These look-through windows, which allow one to see not only the particular displays, but also the store interior, present a somewhat different approach to the problem of the moisture condensation on the windows than is offered here.

Moisture condensation on show windows is the result of the air enclosed in the window display area having water vapor as a constituent of the air. This vapor usually occurs in the form of superheated steam, but when the air comes in contact with a surface cold enough to be below the dew point of the air, moisture will condense on the cold surface. For this reason, if the inside surface temperature of a window is below the dew-point temperature of the inside air, moisture condensation is likely to occur on the window. To be sure that moisture condensation does not take place, the inside surface temperature of the window, $t_{si}$ (Fig. 1), should not be less than the dew-point temperature at the existing conditions of inside temperature ($t_i$) and relative humidity.

### Air Relationships

Naturally, the inside temperature and relative humidity in a window display area and the outside temperature will vary from day to day. It is therefore necessary to be able to show just when moisture condensation can be expected for a particular outside temperature and for any temperature existing inside the window-display area. The curves of Figs. 2 and 3 fill this purpose.

These curves were determined mathematically, making the following two initial assumptions:

(1) Outside wind velocity, 15 mph; inside air = still air
(2) The window consists of a ¼-inch plate glass window having a coefficient of heat transmission $U=1.03$.

The curves can be used directly to determine the maximum allowable relative humidity and specific humidity which can exist at a given inside temperature when the outside temperature is expected to reach a certain minimum.

### Survey of Leading Department Stores

In the investigation of the problem of moisture condensation on show windows it was decided that information should be gathered directly from those who are actually confronted with the problem. This was accomplished by sending a questionnaire to 50 of the larger department stores located in cities in the northern half of the United States.

The questionnaire was prepared with the aim of acquiring the answers to certain particular questions rather than requesting general information of questionable value. The questionnaire, with a summary of the answers received in terms of a percentage of those answering the particular question, follows.

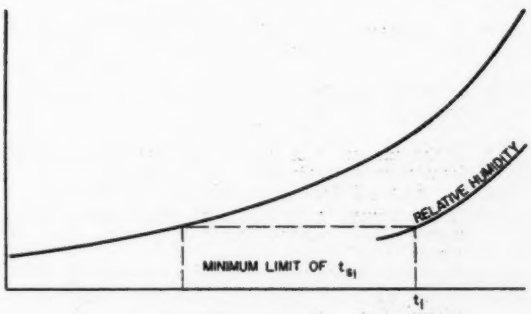



FIG. 1. SKELETON PSYCHROMETRIC CHART

* Abridged by the author from his article originally appearing in *Heating and Ventilating, Reference Section*, December, 1950, a resumé of his thesis for the degree of M.S. in M.E. The study was directed by Prof. H. M. Hendrickson.

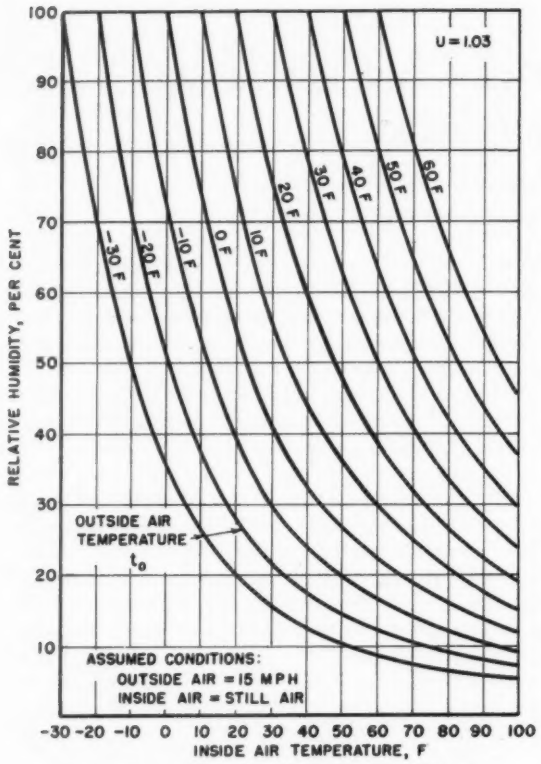



FIG. 2. INSIDE RELATIVE HUMIDITY AT WHICH CONDENSATION OCCURS

## Questionnaire

1—(a) Do you encounter difficulty with moisture condensation on show windows during certain periods of the year?

*Yes, 20%; no, 80%.*

(b) If the answer to 1—(a) is yes, during what months of the year does moisture condensation usually occur? (Underline the months.) Jan. Feb. March April May June July Aug. Sept. Oct. Nov. Dec.

*All answers indicated December, January and February; those who were in the colder areas also included November and March.*

2—(a) Is the air entering the show window spaces heated?

*Yes, 40%; no, 60%.*

(b) If the answer to 2—(a) is yes, what is the temperature of the air entering the spaces? .....deg. F.

*68-74F, 58%; 75-80F, 28%; other, 14%.*

3—(a) Is the air entering the show window spaces directed on the windows?

*Yes, 8%; no, 92%.*

(b) If the answer to 3—(a) is yes, does the air enter from below or from above the window?

*Below, 30%; above, 30%; all around, 40%.*

(c) If the answer to 3—(a) is no, where does the air enter the show window spaces (rear, side, front, top, bottom, etc.)?

*Rear top, 28%; rear sides, 44%; seepage only, 28%.*

4—(a) Is the air which enters the show window spaces dehumidified (moisture removed) before it enters the show places?

*No, 68%; yes, 14%.*

(b) If the air is dehumidified, is it done by passing the air through an air drier using a chemical for absorbing the moisture?
If so, what chemical is used and what is the manufacturer's name and designation of the unit?

*None.*

(c) If the air is dehumidified, is it done by refrigeration?

*Yes, 100%.*

If so, to what temperature is the air cooled?..... deg. F.

*Dew point 50-55F, 50%; 40-50F, 16%; unknown, 34%.*

If the air is cooled, is it then heated up to a more normal temperature:

*Yes, 100%.*

If so, to what temperature is the air then heated? .....deg. F.

*60-65F, 20%; 66-75F, 80%.*

5—If the air entering the show window spaces is not heated, what temperature is allowed to exist inside these spaces (outside temperature, inside temperature, etc.).

*Inside, 25%; as near to outside as can be determined, 75%.*

6—(a) If condensation occurs, is there any physical damage to displays, building, etc.?

*No, 71%; yes, 29%.*

(b) If damage does occur, approximately what percentage of the annual over-all maintenance expenses is used to repair this damage caused by moisture condensation on show windows?

*Nil, 45%; $8 to $12 per window per year, 55%.*

(c) If condensation is not allowed to occur (by dehumidification or other means), approximately what percentage of the annual over-all maintenance expenses is saved per year because of the preventive measures?

*$6 to $8 per window per year, 82%; 4 to 6% of over-all maintenance costs, 18%.*

7—(a) Is there any difficulty with show windows sweating in the warmer summer months?

*No, 100%.*

(b) If so, are the windows connected to an air conditioning system, what temperature is maintained in these spaces? .....deg.. F.

8—If your store did not have show window displays, about what percentage of the total yearly volume of business would you expect to lose?

*10 to 15%, 63%; 15 to 20%, 37%; 40%, 12%. (this 40% value was placed by those which have new branch stores in localities and no "old" customers).*

## Methods of Preventing Condensation

The questionnaire revealed that the following three primary methods are now being employed to prevent moisture condensation on show windows:

(1) Sealing the window display area so that it acts as a still air space

(2) Use of air circulation in the display areas, with warm dry air entering the spaces so as to be directed onto the glass surface.

(3) Dehumidifying the air in the display areas

The most widely used method of preventing moisture condensation on show windows is the process of closing the display area tightly away from the rest of the store. In this way the enclosed air acts as a still air space and the only air which enters the space is the result of leakage through cracks. This method has proved to be quite successful as long as the air leakage from the store is very slight.

Another predominant method is to direct incoming air from the main heating plant directly onto the windows. This method, of course, requires the use of auxiliary air ducts. If the air entering the store proper is to be humidified, as is often done in cold weather, the air which goes to the window display areas must be of low enough relative humidity to keep from inducing moisture condensation rather than preventing it. This air entering the display areas is passed through air ducts above or below the window encasement where the air is allowed to escape directly onto the window surface. This method has proved very successful even in cases where fresh flower displays were used.

Dehumidification of the air to a relative humidity below the critical value in the display areas of show windows is a method which apparently is not used very frequently. In cases where the display areas are not sealed tightly enough, and when these areas are connected to the air conditioning plant, dehumidifying the air appears to be a good, easy way of correcting the problem of moisture condensation or frosting on the window surface. At the present time the author knows of two types of dehumidification units which are relatively low in cost and take a minimum amount of space. One type unit uses silica gel as a dehumidifying agent and operates automatically on an adsorption cycle and a reactivating cycle. Another type unit works on the principle of a refrigeration coil, cooling the air to below the dew point and thus condensing out excess moisture.

The use of warm air circulation as a means of preventing moisture condensation on show windows is probably the best method if the air entering the display areas is directed against the window glass. With this method not only is the temperature of the surrounding air maintained at a more normal level, but the window surface temperature is increased to a point where the critical relative humidity of the air is much higher than is indicated by Fig. 2. Even with the increased allowable relative humidity, difficulty may be encountered because of the incoming air having too high a moisture content due to the air conditioning plant.

If the heating system includes humidifying the air before it enters the display areas, care must be taken to shut off the water sprays in the humidifier if moisture condensation appears on the show windows. The more logical alternative to shutting off the sprays is the preventive measure of having a small dehumidifier located in the display area to withdraw excess moisture from the surrounding air. This small unit would also be useful if the displays included fresh flowers or perhaps a water fountain. In these latter cases, the moisture evaporated from the display will invariably cause condensation to take

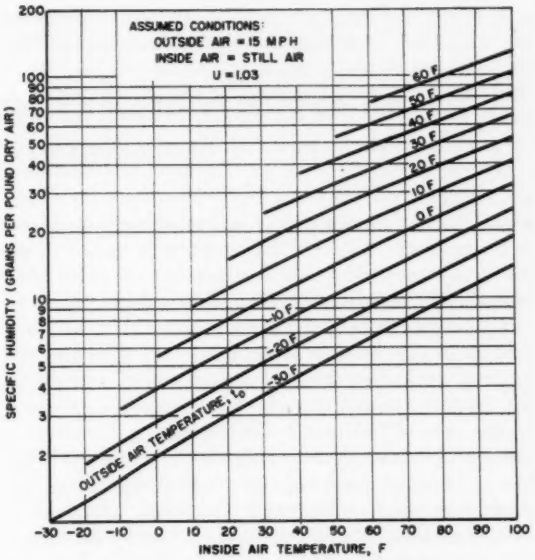



FIG. 3. INSIDE SPECIFIC HUMIDITY AT WHICH CONDENSATION OCCURS

place if no precautions are observed.

Use of fans in windows has the disadvantage of being unsightly, and also a decided disadvantage in that the air motion caused by fans usually disturbs displays in one way or another. Operation of small fans is very helpful as an emergency measure in cases where moisture condensation appears unexpectedly. However, as a permanent preventive measure, it is certainly not recommended.

It is important to note that the problem of moisture condensation on show windows is one that varies extensively from one climatic region to another. For example, the method of sealing the window display areas is one which will work very well in regions such as Seattle, where the temperature does not drop excessively during the coldest months of the year, but may prove unsuccessful in localities where the outside temperature goes below zero continuously during the winter.

### Cost Analysis

Replies to the question regarding the value of display windows and that concerning annual maintenance expenses saved per year by preventing possible damage caused by moisture condensation indicate clearly the high value placed on show windows by the different stores. It seems evident that show window displays will draw in four customers to every one attracted to the store by newspaper advertising. For these reasons some expense is clearly warranted to prevent moisture condensation from occurring on the show windows.

Probably the most inexpensive method of preventing moisture condensation is the process of sealing the enclosed display area from the rest of the store. The only cost in this process is that of labor and a small amount of material incurred during the construction period. In terms of the over-all building cost, this would be of negligible account. However, this method can be used only in certain localities where the minimum yearly temperature would not be much under 15° F. If an attempt is made to seal the windows where the minimum temperature gets much below this, some allowance should be made to use portable fans under the more adverse conditions, and assurance should be had that no damage will occur to sprinkling systems if the temperature in the display area should drop below freezing.

The use of warm air circulation in the display areas to prevent condensation adds to the over-all heating load in the store and requires the use of air ducts and allied equipment. This cost would vary with each installation. However, it can be estimated that the average window and adjacent display area would require an additional investment of about $100 to cover the cost of ducts. If the warm air supplied to the windows is humidified, then a dehumidifier must be placed in the display area to bring down the moisture content of the delivered air. Either of the two usual types of junior size dehumidifiers sells for about $150. Depending upon the size of the window enclosures, it is possible for a dehumidifier unit to serve one or more show windows.

The idea of using double glass windows is probably the most expensive of all the methods, from the standpoint of initial investment. A recent check with plate glass dealers indicates that a window made of single plate glass would cost about $1.25 per sq ft for sizes required under the circumstances and a cost of about $3.75 per sq ft for similar sizes of double glass windows. In the sizes normally employed for show windows, this would mean a comparative cost of about $125 for the single glass as compared to $375 for the double glass. While this additional cost appears favorable when noting the added investment required for the previous method of prevention, the insurance rates on the double windows must be taken into account. The insurance for a single glass show window runs on the order of $10 per year, whereas for a double window the rate is $40 per year because the insurance companies consider that both double windows must be replaced, even though only one of the two glasses should be broken.

A comparison of the first costs and the operating costs for an average installation of equipment to check condensation by the three possible methods, follows.

**Initial Cost**

1. $100 for ducts plus $125 for window glass..$225
2. $150 for dehumidifier unit plus $125 for window glass ..... 275
3. Cost of double window glass ..... 375

**Operating Costs**

1. Cost of furnishing heat to balance heat lost through single plate glass of 100 sq ft area plus $10 insurance on window
2. Cost of operating dehumidifier plus $10 insurance on window
3. Insurance for double window, $40.

If the heat or dehumidifying costs for (1) or (2) are $30 per year or more, then $30 plus the insurance cost equals, or is greater than, that for a double glass window. In some cases, the economics may favor single glass, and in other, the double glass windows.

This study indicated that each particular design must be carefully examined, and all factors considered, before a final decision as to which of the three systems will prove most economical.

**Summary**

The prevention of moisture condensation on show windows is of utmost monetary importance to the merchant, both from the standpoint of increased business and savings in annual maintenance expenditures. Depending on the climatic conditions in the locality, the prevention may require very little additional expense as in the case of sealing the windows, or it may require the use of special equipment at an additional expense of about $250 per window, as in the case where warm air circulation is required along with a dehumidifying unit.

Three main methods of preventing moisture condensation on the show windows are:

(1) Completely sealing the show window spaces
(2) Using warm air circulation in the window spaces
(3) Using a small dehumidifier in the window display area.

The method of sealing the display area from the surroundings is one which is economical and effective in climates where the minimum winter temperature does not drop much below 15° F. If the temperature does go much below this minimum, then some means of auxiliary heating should be employed to prevent not only moisture condensation, but also to avoid the possibility of the sprinkler system freezing, in the event the display area should have a temperature that is below 32° F.

Where the minimum winter temperature is much below zero, it is advisable to incorporate a means of using circulated air in display spaces, the air coming from the main heating plant of the store. This method

*(Continued on page 32)*

# Conference of National Coal Experts Prepares for Urgent State Development

ONE OF THE MOST SIGNIFICANT and constructive meetings ever held in the state of Washington on the subject of the industrial development of the most plentiful of its natural resources, subbituminous coal deposits, was held at Centralia on December 7-8, 1951, under the auspices of Coal Research, Inc., a non-profit organization of scientists and industrialists, with Dr. H. K. Benson, Emeritus Professor of Chemical Engineering at the University of Washington, as program chairman.

Vernon F. Parry, chief of the coal branch fuels technology division, of the Denver office of the U. S. Bureau of Mines, who worked out the lignite processing and by-products studies for the Alcoa Texas project described elsewhere in this issue of *Trend*, made one of the key addresses of the meeting. He reported that, with lignite costing $2.25 per ton as stripped and processed, a full utilization of by-product credits results in a net fuel cost of 0.89 mills per kilowatthour. Labor, supplies, and fixed charges on the capital investment will bring the total production cost for electrical energy up to 2.5 to 3.5 mills. He explained that Texas lignite and Washington so-called low-grade subbituminous coals are actually high grade for chemical purposes and for reactivity. The Texas project sets the pattern for combined chemical and power developments in the Northwest, using Washington's huge deposits of low-rank coal.

Chemicals being derived from natural gas and from coal gas were clearly described by P. T. Martin, process engineer for Spencer Chemical Company, Pittsburgh, Kansas, and in a paper by Carl E. Lesher, chemical engineer of Pittsburgh, Penn., while Harlan Nelson of Cleveland, Ohio, described his work on coal gas producers. Another eastern expert, R. W. Dougherty, industrial engineer of the Bureau of Mines at Louisiana, Missouri, described hydraulic transportation of coal by pipe-line, while others discussed gas pipe-line, rail, and truck transportation. The existence of an almost inexhaustible coal supply was explained by Mr. Parry and by Parke D. Snavely of the U. S. Geological Survey fuels branch at Portland, Oregon. The low cost of strip-mining coal lying near the surface was discussed by Dr. H. F. Yancey of the U. S. Bureau of Mines office at the University of Washington, with whom William Strain and Earl McMillan, coal-mine operators, agreed. Mechanized underground mining having large production and low cost was explained by John H. Emrick of the Joy Mfg. Company, and Harry S. Patrick of the Roslyn-Cascade Company.

D. W. Harris, representing the Babcock & Wilcox Company, discussed power-generation aspects and showed slides of modern steam-electric plant installations, citing production cost of three-eighths of a cent per kilowatthour for local conditions. Dr. R. W. Moulton, Professor of Chemical Engineering at the University of Washington, described a powdered coal gasification retort which he has developed.

Dr. Paul J. Raver, Bonneville Power Administrator, discussed the government's proposed 300,000 kilowatts of steam-electric plants with relation to the hydroelectric program now under way. Comparisons between steam and hydro production costs for carrying the load of the Northwest Power Pool, using various fuels including by-product char were explained by Assistant Professor Floyd D. Robbins of the Electrical Engineering Department of the University of Washington, who showed the flexibility of steam-plant operation and its competitive place in the economy of the Northwest. The concluding item on the program consisted of a discussion by F. B. Farquharson, Director of the Engineering Experiment Station of the University of Washington, on the now half completed 2.2 million kilowatt steam-electric plant construction program of the Tennessee Valley Authority under conditions for combined hydro-steam plants almost identical with those of the Northwest.

Willis T. Batcheller, consulting engineer of Seattle, summarized the evidence presented by these experts. Current steam-electric plant construction costs of around $150 per kilowatt compared with hydro costs of $350 per kilowatt which will increase as the more economical developments are built, and the use of low-cost coal, or char, clearly show the economic and commercial feasibility and the employment advantages of duplicating the Texas Alcoa program at Vancouver, Washington, and elsewhere.

The large and enthusiastic attendance of 140 men was in itself ample evidence of the keen interest generally exhibited in the subject of coal. There appears to be no doubt that the defense program and the serious power shortage will soon necessitate a comprehensive coal development in the state of Washington.

# Engineering Research Dividends

**Recent theses for advanced degrees, which were submitted as reports on Engineering Experiment Station research projects, will regularly appear in abstract form in *The Trend*. Complete copies of these theses are available for reference at the University of Washington Library. Address inquiries to the Director of the Engineering Experiment Station.**

HUFFORD, G., "On the Propagation of Horizontally Polarized Waves Over Irregular Terrain." M.S. in Electrical Engineering, 1948.

With the coming of additional communication services at high radio frequencies, it has become increasingly important to analyze the effects of irregular and inhomogeneous terrain upon the propagation of electromagnetic radiation. Even a theoretical analysis of propagation over a uniform plane earth requires involved mathematical considerations, and the problem of a rough earth seems so formidable that the literature reports few attempts at solution. The writer has applied the powerful method of integral equations in an attempt to obtain such a solution. This attack reduces the differential equations to a simpler set of integral equations of one less dimension which include the boundary conditions. He first solves the known problem of propagation over a uniform plane to demonstrate the method and then applies the method to the solution for rough terrain. The end result is a single integral equation whose solution is an approximation to the exact answer. The thesis also includes a discussion of the problem of obtaining a numerical solution for given boundary conditions.

SENGUPTA, M., "A Study of the Pressure Welding Process." M.S. in Mechanical Engineering, 1951.

The following problems in pressure welding were investigated and reported in this thesis: (1) the determination of metals, or pairs of metals, suitable for joining by cold-pressure welding, (2) the determination of suitable shapes for the welding dies, (3) the relationship between welding pressure and strength of the weld, and (4) the determination of the metallurgical structure of cold-pressure welds. The experimental cold-pressure welding was chiefly confined to aluminum alloy 3SO, hot-rolled copper, and cold-rolled brass, in the form of sheet metal about 0.075 in. thick. Welding dies of cold-rolled steel were used in three shapes. Within a welding pressure of 2,000 lb, cold-pressure welds were produced between pieces of aluminum alloy 3SO, between pieces of hot-rolled copper, and between adjacent pieces of the aluminum alloy and copper. Cold welds were also produced between hot-rolled copper and cold-rolled brass, but attempts to cold-weld two pieces of cold-rolled brass failed. Size and shape of the welding die played an important role in the cold-weld process.

RIPPE, B. K., "Wave Pressures on Vertical Bulkheads." M.S. in Civil Engineering, 1951.

The pressures created by waves which do not break but instead form standing, or clapoti, waves have not been hitherto critically examined. The need for such examination is seen in the repeated failure of breakwaters and jetties. The presence of a suitable wave tank and wave generator at the University of Washington prompted the research described in this thesis. A vertical bulkhead, with small holes located at predetermined intervals, was fastened in the channel. The holes were sealed on the water side by rubber membranes, and on the other side the pressure cells were mounted. Pressure measurements were made through a unique application of electrical strain gages and electronics. Experimental data consist of motion-picture film and Brush recordings of fifteen test runs in which the unobstructed wave height was 6 inches, wave length 7 feet, and wave period 1.25 seconds. Results of the experiment are not inclusive or conclusive enough to warrant publication of a method for predicting unbalanced pressure resulting from a knowledge of deep-water wave characteristics. Several broad conclusions were established concerning the location of maximum pressure and the maximum height to which the clapoti wave might be expected to rise. Finally, an application of model laws was used to extend experimental results for comparison with some cited values of wave pressure.

SHIMIZU, T., "The Prediction of Sieve-Plate Point Efficiencies for Vapor-Liquid Systems." M.S. in Chemical Engineering, 1951.

The purpose of the investigation reported in this thesis was the correlation of experimental data so that bubble plate efficiencies may be predicted from

*(Continued on page 32)*

# Notes and Comments

## ENGINEERS IN THE NEWS

**R. N. KUSIAN,** Acting Director of the University's Environmental Research Laboratory, presented a paper, "Environmental Research: An Aid to Industrial Safety," before the Governor's Safety Conference which met at Olympia November 6-7.

**P. L. BALISE,** Instructor in Mechanical Engineering, read a paper on "Application of Xenon Flashtube to Scattered Light Polariscope," before the Society for Experimental Stress Analysis which met in Philadelphia, November 28-30.

**R. G. HENNES,** Professor of Civil Engineering, will attend the annual meeting of the Highway Research Council to be held in Washington, D. C., January 15-18, where he will present a paper co-authored by Assistant Professor **J. R. CLANTON,** on "Stability and Durability of Plant-Mix Macadam." This report has grown out of work done on Station Project No. 6. On recommendation of the State Council for Highway Research for which Professor Hennes is chairman, the **INSTITUTE OF FOREST PRODUCTS** has been asked to conduct a study on "Natural Resource Roads" for the W.S.H.D.

**T. L. GERSHUN,** whose article, "Moisture Condensation on Enclosed Show Windows," appears in this issue, now holds a research fellowship sponsored by Standard Oil of Indiana at Iowa State University.

**H. M. CHITTENDEN,** Associate Professor of Civil Engineering, has been appointed by the State Commissioner of Public Lands to the 5-man Advisory Board on Surveys and Maps.

**N. KETZLACH,** whose thesis on "Olivine as a Source of Magnesium," is briefed on pp. 21-24, is a chemical engineer on the Hanford project.

**F. B. FARQUHARSON,** Director of the Station, attended the AASHO-ASCE meeting held in New York, October 23, where he met with the Joint Committee to Study Plate Girders to work out details of a pending contract for a study of deep-plate girders in the Structural Research Laboratory.

**R. A. HECHTMAN,** Associate Professor of Structural Research, attended the meeting of the American Welding Society held in Detroit, October 16, and read a paper co-authored by **D. VASARHELYI** on "A Determination of Strain Energy Distribution and True Stresses in the Plastic Range in Plates with Openings."

## NEW RESEARCH PROJECTS

**Project No. 122. Quenching Constants for Two-Phase Media.** J. I. Mueller, Assistant Professor of Mineral Engineering, Supervisor; W. M. Yim, Research Fellow.

**Project No. 123. Construction of Two 100,000-lb Fatigue Machines for Structural Testing.** R. A. Hechtman, Associate Professor of Structural Research.

**Project No. 125. Bonneville Power System Relaying.** F. R. Bergseth, Assistant Professor of Electrical Engineering, Supervisor; E. A. Levin, R. L. Schoenman, Research Fellows. Sponsored by Bonneville Power Administration.

**Project No. 126. VHF Field Studies.** H. M. Swarm, Assistant Professor of Electrical Engineering. Sponsored by National Bureau of Standards.

**Project No. 127. Continuous Production of Esters in Packed Columns.** R. W. Moulton, Professor of Chemical Engineering, Supervisor; G. C. Szego, Research Fellow.

**Project No. 128. Optimum Design of Deliberately Nonlinear Servomechanisms.** T. M. Stout, Instructor in Electrical Engineering, Supervisor; C. H. Shah, R. von Tobel, Research Fellows. Sponsored by Office of Naval Research.

**Project No. 129. Corona Studies—Effect of Wind.** F. B. Farquharson, Director of the Engineering Experiment Station, G. S. Smith, Professor of Electrical Engineering, A. B. Jacobsen, Instructor in Electrical Engineering.

**Project No. 131. Heavy Concrete.** H. P. Mittet, Assistant Professor of Civil Engineering, Supervisor; Z. T. Zia, Research Fellow. Sponsored by the General Electric Company, Hanford, Washington.

**Project No. 132. Highway Classification.** R. G. Hennes, Professor of Civil Engineering, Supervisor; Willa W. Mylroie, Office Engineer. Sponsored by Washington State Council on Highway Research.

**Project 133. Chassis Dynamometer.** Michael Guidon, Assistant Professor of Mechanical Engineering, Supervisor; A. K. Choudhuri, Research Fellow.

**Project No. 134. Design Study of a Rack-and-Pinion Overriding Clutch Form of Internal Combustion Engine.** Michael Guidon, Assistant Professor of Mechanical Engineering, Supervisor; P. P. R. Choudhury, Research Fellow.

**Project No. 135. Investigation of Poisson's Ratio and Other Mechanical Properties of Solids.** B. D. Mills, Jr., Professor of Mechanical Engineering, Supervisor; A. K. Banerjee, Research Fellow.

## NEW REPRINTS

**Reprint No. 46.** "Olivine Sand Research," G. S. Schaller, W. A. Snyder, *Foundry,* May, 1951.

**Reprint No. 47.** "On the Latent Heat of Fusion and the Hole Theory," N. R. Mukherjee, *Jour. Chem. Phys.,* April, 1951.

**Reprint No. 48.** "Absorption on a Semi-Works Scale," L. A. Lundberg, D. A. Pearson, F. M. West, J. L. McCarthy, *Chem. Eng. Prog.,* May, 1951.

**Reprint No. 49.** "Effects of Light Peening on the Yielding of Steel," H. L. Harrison, B. D. Mills, Jr., *Weld. Jour. Res. Supp.,* May, 1951.

**Reprint No. 50.** "Fermentation to Ethanol of Concentrated Calcium, Magnesium, and Ammonium Sulphite Waste Liquor I)," H. D. Agar, J. L. McCarthy, and "Continuous Laboratory Propagation of Sulphite Waste Liquor Yeast (Sulphite Waste Liquor II)," A. E. Markham, H. D. Agar, J. L. McCarthy, *TAPPI,* March, 1951.

**Reprint No. 51.** "Characteristics of Electric Strain Gages at Low Temperatures," E. E. Day, A. H. Sevand, *Proc. Soc. Exper. Stress Anal.,* Vol. VIII, No. 1.

**Reprint No. 52,** "Welded Reinforcement of Openings in Structural Steel Steel Members," D. Vasarhelyi, R. A. Hechtman, *Weld. Jour. Res. Supp.,* April, 1951.

**Reprint No. 53.** "Ionophoretic Analysis in Agar Gels," Q. P. Peniston, H. D. Agar, J. L. McCarthy, *Analyt. Chem.,* July, 1951.

**Reprint No. 54.** "A Superposition Method for Calculating the Aeroelastic Behavior of Swept Wings," R. B. Brown, K. F. Holtby, H. C. Martin, *Jour. Aer. Sci.,* August, 1951.

**Reprint No. 55.** "Casting Surfaces Produced in Olivine Molding Sand," G. S. Schaller, A. M. Nelson, *Foundry,* October, 1951.

### LIGNITE PROCESS HITS THE MARK

*(Continued from page 16)*

Lignite char has a volatile content of about 25 percent and a heating value of 10,600 Btu. per lb. The process gas has a heating value of 150 Btu. per cu. ft.

A lignite processing unit of this type is designed for a capacity of 25 tons per hour. Large plants would have one battery or more of such units. Overall thermal efficiency of the operation is about 91 percent.

---

### MOISTURE CONDENSATION ON ENCLOSED SHOW WINDOWS

*(Continued from page 28)*

requires an additional investment of about $250, if the store uses an air conditioning plant, since it would probably be necessary to use a small dehumidifier in the display area for extracting any excess moisture from the air.

Where the windows have been sealed, it is often necessary to use precautionary measures at the times when the window displays are being changed; otherwise the air entering from the store at these times may cause the windows to fog over.

---

### PREDICTION OF SIEVE-PLATE POINT EFFICIENCIES FOR VAPOR-LIQUID SYSTEMS

*(Continued from page 30)*

a knowledge of the mass transfer coefficients, the size of the bubbles, and their rates of rise. The following conclusions were drawn:

1. The fraction voids increase slightly with gas flow rates but decrease with higher liquid levels.
2. The number of transfer units based on either liquid or gas phase concentrations increases with liquid level but varies only moderately with gas rate.
3. The number of transfer units based on the liquid phase concentrations varies almost inversely with the liquid rate, indicating little effect of liquid rate on $k_L a$.
4. The effective interfacial area using Higbie's equation is relatively constant for humidification and for absorption and desorption for carbon dioxide.
5. The interfacial areas calculated from Gilbert's stroboscopic measurements of initial bubble size on the two-row plate are 50 to 75 per cent of the effective values based on Higbie's equation. This indicated that the equation predicts somewhat too low values for $k$.
6. Point efficiencies for sieve plates of the same general design as used in this investigation presumably can be predicted from the equations and correlations presented, providing that the physical properties of the liquid are not too dissimilar from those of water.

# PUBLICATIONS

*of the*

# ENGINERING EXPERIMENT STATION

## UNIVERSITY OF WASHINGTON

Requests for copies of publications should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

## BULLETINS

48. The Influence of Pipe Thickness on Re-Entrant Intake Losses. Charles William Harris. 35 pp. 1928.
55. Vacuum-Tube Control for Electric Wind-Tunnel Balances. Fred Scoville Eastman. 20 pp. 1931.
56. Constant Flow Characteristic of the Plane Orifice in Proximity to Side Walls. Charles William Harris. 18 pp. 1931.
58. Preliminary Tests of Thirteen Washington Coals in a Powdered Coal Boiler Plant at the University of Washington. George Samuel Wilson, Harry Fagan Yancey, and Joseph Daniels. 27 pp. 1931.
60. An Electromagnetic Balance for Force Measurement of Current Control. Fred Scoville Eastman, 29 pp. 1932.
61. Hydraulic Flow Characteristics of a Square-Edged Intake. Charles William Harris. 21 pp. 1932.
67. The Doherty Washer Cooler. Sybren Ruurd Tymstra. 61 pp. 1932.
72. The Derivation of the Mean Temperature Difference Between a Saturated Gas and a Cooling Liquid, and also the Derivation of the Mean Velocity of Such Gas. Sybren Ruurd Tymstra. 19 pp. 1933.
73. The Production of Sodium Nitrite from Arced Nitrogen. Edgar Allen Loew and Warren Lord Beuschlein. 54 pp. 1933.
74. The Deformation of Hard Grade Reinforcing Steel During and After Construction in a Reinforced Concrete Building. Sergius Ivan Sergev. 33 pp. 1933.
75. The Water Tube Gas Condenser. Sybren Ruurd Tymstra. 24 pp. 1934.
76. Kaolin and China Clay in the Pacific Northwest. Hewitt Wilson. 184 pp. 1934.
77. A Study of Fundamental Relations of the Mathematical Theory of Elasticity. Arthur Melvin Winslow. 25 pp. 1934.
78. Hydroelectric Power in Washington. Part III, A Brief on Proposed Grand Coulee Dams. Carl Edward Magnusson. 32 pp. 1935.
79. Cycloidal Propulsion in Air. Part I, Cycloidal Propulsion Theory; Part II, Cycloidal Propeller Development at the University of Washington. Frederick Kurt Kirsten. 87 pp. 1935.
81. Influence of Two Secondary Factors in Weir Measurement. Charles William Harris. 16 pp. 1935.
84. Equations for Calculating Three Phase Symmetrical Components. Gordon Russell Shuck. 32 pp. 1935.
85. Discharge of Three Commercial Cippoletti Weirs. Robert Bowman Van Horn. 32 pp. 1935.
86. Flexure Pivots to Replace Knife Edges and Ball Bearings. Fred Scoville Eastman. 47 pp. 1935.
87. Open Water Testing of Ship Models. Thomas McKie Rowlands. 20 pp. 1935.
88. The Properties of Quartz Sands Washed from Kaolins of the Pacific Northwest. Hewitt Wilson and Frank Joseph Zvanut. 42 pp. 1936.
90. Hydroelectric Power in Washington. Part IV, Regional Electric-Power Transmission. The Grid System. Carl Edward Magnusson. 51 pp. 1936.
91. The Analysis and Control of Landslides. Robert Graham Hennes. 57 pp. 1936.
92. Moment Equations. A Method of Analysis for Continuous Beams and Rigid Frames. Alfred Jensen. 88 pp. 1937.
93. Electric Power Markets in Washington. Part I, Electric Heating of Residences. Carl Edward Magnusson. 40 pp. 1937.
94. Evaporative and Surface Cooling. George Samuel Wilson and William Lyle Dudley. 18 pp. 1937.
95. Hydroelectric Power in Washington. Part V, A Bibliography of Technical Papers, 1926-1935. Carl Edward Magnusson. 204 pp. 1937.
96. Hydroelectric Power in Washington. Part VI, International Boundary Waters. Carl Edward Magnusson. 17 pp. 1937.
97. Strength of Concrete for Mixes of Various Proportions. Ira Leonard Collier. 28 pp. 1938.
98. Geology and Its Relation to the Occurrence of Oil in Washington. Charles Edwin Weaver. 16 pp. 1938.
99. Electric Power Markets in Washington. Part II, Residence Service Markets and a Regional Power Grid. Carl Edward Magnusson. 92 pp. 1938.
100. Modernization of a Transit System. Factors that Determine the Choice of a Vehicle. George Lisle Hoard. 36 pp. 1940.
101. Buckling Criteria and Design of Two-Story Columns. Sergius I. Sergev. 48 pp. 1940.
102. An Investigation of Prestressed Stays. T. M. Rowlands and F. C. Smith. 36 pp. 1941.
103. Bismuth Bridge Magnetic Flux Meter. George Sherman Smith. 48 pp. 1940.
104. The Telechronometer, Telephone Service Measurement in Units of Time. Lyall Baker Cochran. 68 pp. 1941.
105. Theory of Flexure of Structural Members of Non-uniform Section Alfred L. Miller. 68 pp. 1940.
106. The Shearing Strength of Cement Mortar. Frederick C. Smith and Robert Q. Brown. 32 pp. 1941.
107. A Geologic Interpretation of the Failure of the Cedar Reservoir, Washington. J. Hoover Mackin. 30 pp. 1941.
108. Silica Sands of Washington. Hewitt Wilson, Kenneth G. Skinner and Albert H. Couch. 76 pp. 1942.
109. The Number of Teeth in Contact as a Vibration Factor in Involute Cut Gears. Sybren Ruurd Tymstra. 16 pp. 1942.
110. Solutions for Torsional Vibration Frequencies by Energy Method. Arthur Melvin Winslow. 22 pp. 1943.
111. Stabilized Earth Blocks for Protective Construction. Robert G. Hennes. 24 pp. 1943.
112. Hydraulic Models. Charles W. Harris. 17 pp. 1944.
113. The Theoretical Behavior and Design of Initially Curved Struts Under an Intermediate Concentric Axial Load. Sergius I. Sergev. 32 pp. 1945.
114. The Effect of Shearing Forces on the Deflection and Strength of Beams. Sergius I. Sergev. 20 pp. 1947.
115. The Influence of Random Roughness on Flow in Pipes. Charles W. Harris. 19 pp. 1949.
116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part I, Investigations Prior to October, 1941. F. B. Farquharson. 103 pp. 1949.

116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part II, Mathematical Analyses. F. C. Smith and G. S. Vincent. 63 pp. 1950.

116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part III, The Investigation of Models of the Original Tacoma Narrows Bridge Under the Action of Wind. F. B. Farquharson. (In preparation.)

117. Production of Wood Coke from Waste Wood. Warren L. Beuschlein. 40 pp. 1950.
118. Investigations in Aeronautics from the Department of Aeronautical Engineering. Edited by R. M. Rosenberg. 120 pp. 1951. Price: Two dollars.
119. The Extremum Principles of the Mathematical Theory of Elasticity and Their Use in Stress Analysis. (The Walker-Ames lectures of the Spring Quarter, 1950.) W. Prager (Brown University). 30 pp. 1951. Price: 75 cents.

## REPORTS

2. Iron and Steel Manufacture in Washington, Oregon, California, and Utah. Joseph Daniels. 69 pp. 1929.
3. Coal in Washington. Joseph Daniels. 17 pp. 1934.
4. Water Resources of Washington. Richard Gaines Tyler. 61 pp. 1938.
5. The Terminal Plan: An Improved System of Urban Transportation. Austin Vitruvius Eastman. 64 pp. 1938.
6. Chemical Utilization of the Subbituminous Coals of Washington. Lorentz A. Conradi. 83 pp. 1950.

## TECHNICAL NOTES

3. The Theory of Fractional Parts Developed for Structural Beam-Column Members Preceded by an Elementary Discussion of Simple Beam and Column Design. Sybren Ruurd Tymstra. 32 pp. 1943.
4. Gaging Chart for Horizontal Cylindrical Tanks with Flat Heads or with Convex Heads. Sybren Ruurd Tymstra. 4 pp. 1944.
5. Gaging Chart for Cylindrical Tanks with Different Types of Heads. Sybren Ruurd Tymstra. 7 pp. 1945.
6. The Heat Pump for Residential Heating. G. S. Smith, H. Christensen. and A. Presson. 23 pp. 1948.

Prof. S. Sergev
306 More